

**“Effects of K, Mg and S fertilizers on growth and
yield of Bt. cotton grown on loamy sand soil of
middle Gujarat”**

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*Master of Science***

(AGRICULTURE)

**IN
SOIL SCIENCE & AGRICULTURAL CHEMISTRY**

**BY
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B.Sc. (Agri.)**

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ANAND -388110**

Reg. No. 04-1656-2011

**Effects of K, Mg and S fertilizers on growth and
yield of Bt. cotton grown on loamy sand soil of
middle Gujarat**

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ABSTRACT

A field experiment was conducted at Micronutrient Project (ICAR) experimental site, College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *kharif* season of the year 2012 to study the **“Effects of K, Mg and S fertilizers on growth and yield of Bt. cotton grown on loamy sand soil of middle Gujarat”**. The soil of experimental plot was loamy sand in texture. It was low in available nitrogen (100 kg ha^{-1}). It was medium in available phosphorus (31.8 kg ha^{-1}) as well as, available potash (238 kg ha^{-1}) and sufficient in available magnesium ($7.2 \text{ me } 100 \text{ g}^{-1}$ of soil) but low in available sulphur (5.7 mg kg^{-1}). Among micronutrient cations Zn (0.4 mg kg^{-1}) was deficient and Fe (6.6 mg kg^{-1}) as well as Mn (7.8 mg kg^{-1}) were medium, while Cu (1.23 mg kg^{-1})

⁻¹) status was high. It was low in organic carbon (4.3 g kg⁻¹), with pH 7.9. The experiment was laid out in a factorial randomized block design with 8 treatment combinations and four replications. The treatments consist each factor with two levels viz., (1) K₂O = no K, K₁₂₀ = 120 kg K ha⁻¹, (2) MgO = no Mg, Mg₄₀ = 40 kg Mg ha⁻¹ and (3) S₀ = no S, S₄₀ = 40 kg S ha⁻¹.

The results revealed that the effect of individual application of K @ 120 kg ha⁻¹ was found beneficial to reduce the drying of leaves, resulted in relative good growth of plant upto harvest and maintained significantly higher plant stand over control.

The significant effect of individual application of K @ 120 kg ha⁻¹, Mg @ 40 kg ha⁻¹ and S @ 40 kg ha⁻¹ was noticed to improve the stalk and seed cotton yield except application of Mg in case of seed cotton yield. The improvement in seed cotton yield due to application of K, Mg and S was to the tune of 12.6, 0.8 and 24.6 per cent over control, respectively corresponding per cent improvement in stalk yield was 48.6, 18.9 and 19.3.

The oil content in cotton seed was improved significant due to S application @ 40 kg ha⁻¹ (19.8 %) over control (17.1 %).

In general, K, Mg and S content in leaf were increased due to their respective application at 30, 60 and 90 DAS. Similarly at

□.....
.....*Abstract*

harvest K, Mg and S content in leaf, stalk, lint and seed were also increased due to corresponding applications of K, Mg and S.

The absorption of K, Mg and S was increased with their application in Bt. cotton plant.

The overall soil contents of K and S were declined with the time indicated utilization of nutrient for cotton growth, while Mg status was unaffected with the time. At harvest application of K was found to maintain the K status in soil as compared to no K. Application of Mg also found to increase the Mg status in soil and also S status of soil was affected due to its application.

From foregoing results it is concluded that to overcome the problem of reddening/parawilt of Bt. cotton in soil having medium available potassium and low available sulphur status application of 120 kg K₂O and 40 Kg S ha⁻¹ is required.

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CERTIFICATE

This is to certify that the thesis entitled “**Effects of K, Mg and S fertilizers on growth and yield of Bt. cotton grown on loamy sand soil of middle Gujarat**” submitted by **Solanki Sandip M. (Reg. No. 04-1656-2011)** in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** of the Anand agricultural University is a record of bonafide research work carried out by him under my personal guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand

(V. P. Ramani)

Date: /11/2013

MAJOR GUIDE

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LIST OF ABBREVIATIONS

%	: Per cent	K₂O	: Potassium oxide
@	: At the rate of	MgO	: Magnesium oxide
AAU	: Anand Agricultural	S	: Sulphur
	University		
atm	: atmosphere	MgSO₄	: Magnesium sulphate
BACA	: B. A. College of	FeSO₄	: Ferrous sulphate
	Agriculture		
C.D.	: Critical difference	ZnSO₄	: Zinc sulphate
C.V.	: Co-efficient of variance	MOP	: Muriate of potash
cm	: Centimeter	KCl	: Potassium chloride
cv.	: Cultivar	Bt.	: Bacillus Thuringiensis
Day⁻¹	: Per day	Min.	: Minimum
dS/m	: Desi Siemens per meter	OC	: Organic carbon
EC	: Electrical conductivity	P₂O₅	: Phosphorus pentoxide
et al.	: Et alii; and co-workers	pH	: Negative logarithm of H ⁺
etc.	: Etcetera; and rest, so on	ppm	: Parts per million
Fig.	: Figure	Reg.	: Registration
g	: Gramme	No.	: Number
hr⁻¹	: Per hour	viz.,	: Namely
ha⁻¹	: Per hectare		
i.e.	: That is	NS	: Non-significant
ICAR	: Indian Council of	°C	: Degree Celsius
	Agriculture Research		
kg	: Kilogram		
m	: Meter		
Max.	: Maximum		
mg	: Milligram		
S.E.m.	: $\pm$ Standard error of mean		
Sig.	: Significant		

I. INTRODUCTION

Cotton (*Gossipium hirsutum* L.) popularly known as “the white gold” is an important commercial fiber crop grown under diverse agro-climatic conditions around the world. It provides fiber, a raw material for textile industry along with cotton seed besides cotton seed oil and plays a vital role in economy of the country. Textile industry is supposed to be a number one enterprise, which consumes nearly 70 per cent of total fiber produced (Itnal, 2004). In India, cotton is grown over an area of about 10.31 million ha with a total production of 30.5 million bales. India ranks second in both area and production of cotton after China. The productivity of cotton is 528 kg ha⁻¹ which is lower than the world average of 759 kg ha⁻¹ (Anon., 2011).

The nutrient requirement of cotton to produce a tonne of cotton yield is estimated at 43-53, 2-8 and 45-53 kg of N, P and K, respectively (Kalaichelvi *et al.*, 2006). For cotton, the nutrient contribution from soil is accounted for 28.90, 26.40 and 10.60 %, through fertilizers 32.23, 34.40 and 70.30 % and from organics 18.80, 12.26 and 21.89 % of N, P and K, respectively (Kalaichelvi *et al.*, 2006). The cotton is a heavy feeder crop; therefore, it needs better nutrient management for higher cotton yield.

Potassium is a mobile element and is an essential macronutrient for all living organisms required in large amounts for

normal growth and development (Marschner, 1986). Potassium deficiency can limit the accumulation of crop biomass. This is attributed to that, K increases the photosynthetic rates of crop leaves, CO₂ assimilation and facilitates carbon movement (Sangakkara *et al.*, 2000). Also, K nutrition has pronounced effects on carbohydrate partitioning by affecting either phloem export of photosynthates (sucrose) or growth rate of sink and/or source organs (Cakmak *et al.*, 1994).

Potassium remains in an ionic form in the plant cells and tissues and plays an important role in osmoregulation. Potassium plays an important role in fiber development and the turgor driven expansion of fiber cells ultimately determines the fiber length (Dhindsa *et al.*, 1975; Cakmak *et al.*, 1994; Cassman *et al.*, 1990 and Oosterhuis, 1994). Equally important is its role in enzyme activation. There are more than 50 enzymes which either completely depend on or stimulated by K.

The uptake of Mg is similar to that of Ca. Due to cationic competitive effects; uptake of Mg is lower than K or Ca. The most important function of Mg is its occurrence in the centre of the chlorophyll molecule. The other major role of Mg²⁺ is as a cofactor in enzymes activating photophosphorylation processes. Inadequate levels of Mg in the plant can inhibit CO₂ assimilation. It is also

required to activate the enzyme ribulose diphosphatecarboxylase. It plays an important role in N-metabolism. Proportion of protein-N decreases in Mg deficient crop, caused by the dissociation of the ribosomes. Magnesium helps in translocation of cellulose and determines fiber quality.

The Mg deficiency leads to "reddening of leaves" in the presence of high calcium. In contrast to Ca, deficiency symptoms are initially observed in the older leaves. The reddening occurs due to reduced photosynthetic activity in the plant, which may be due to immobilization of Mg in cotton. Sometimes the Mg deficiency is confused with natural ageing late in the season (Ramesh *et al.*, 1999).

Sulphur is a constituent of amino acids (cysteine and methionine), coenzyme A, thiamine and biotin. It plays an important role in protein synthesis by the formation of disulphide bonds between polypeptide chains. Sulphur is taken up by the plants as SO_4^{2-} and is assimilated in the plants.

Sulphur deficient plant has increased levels of amines, amides and nitrates due to restricted synthesis of nitrogenous compounds in to protein. For this reason deficiency of both nitrogen and sulphur causes chlorosis with resultant yellowing of leaves. Sulphur is relatively immobile within plant. Hence, newer leaves usually show chlorosis earlier than the older leaves. The deficiency is first seen on

upper young leaves. Leaves first turn to light green to light yellow followed by pronounced yellowing and deficient plants show high levels of NO_3^- and accumulation of amide -N.

With the introduction of Bt. cotton, its growing area and production have increased in Gujarat and soil gets exhausted for all the nutrients due to continuous uptake of all nutrients by Bt. cotton especially in a situation where only N is recommended. The root system of Bt. cotton is relatively shallower as compared to convention hybrid cotton varieties, therefore limiting the nutrient uptake by Bt. cotton and nutrient disorders occur, which is the most important limiting factors in Bt. cotton production.

In cotton, major problem is deficiency of nitrogen; however, recent research has revealed that the other major nutrient (K) and secondary nutrients (Mg and S) deficiency problems are also hampering cotton production. The yellowing or reddish brown colour of cotton leaves is a serious problem beside leaf shedding or drying of whole plant in some cotton growing areas of Gujarat. Therefore, present study entitled “Effects of K, Mg and S fertilizers on growth and yield of Bt. Cotton grown in loamy sand soils of middle Gujarat” was planned with the following objectives.

Objectives:

.....*Introduction*

- (1) To evaluate the effects of K, Mg and S application on growth and seed cotton yield of Bt. cotton.
- (2) To evaluate the effects of K, Mg and S application on chemical composition and oil content of cotton seed.
- (3) To evaluate the effects of K, Mg and S application on nutrients status of soil.

II. REVIEW OF LITERATURE

Cotton, being a major agricultural cash crop in India, has a major impact on overall Indian agriculture sector. Cotton is considered as the “king” of textile fiber in India and is one of the most significant contributors to our national economy. Presently 4.59 million tonnes cotton (27 million bales of 170 kg each) is produced in India, which constitutes about 18% of the world cotton production.

In India, cotton is primarily cultivated in three distinct agro-ecological zones (North, Central and South). Approximately 65 % of India’s cotton is grown as rainfed and 35 % is grown on irrigated land. The Northern zone is almost totally irrigated, while the irrigated area is much lower in the Southern (40 % irrigated) and Central zone (23 % irrigated). The Central zone is home to about 65 % of the total cotton area of our country. In addition, cotton is also cultivated in a small area in non-traditional states such as Uttar Pradesh, Orissa, West Bengal and Tripura. It is inherently a semi-perennial crop, but it is being grown as an annual/seasonal crop in India.

The Central zone is comprised of the rainfed tracts of Madhya Pradesh, Maharashtra and Gujarat. The predominant area is under black

soil (*Vertisols*), which is subjected to runoff, soil erosion and nutrient losses. This area is known as a *hirsutum*, *arboreum*, *herbaceum* and hybrid cotton species zone in which cotton is grown in the monocropping or intercropping system. The zone is characterized by a hot, semi-arid climate, with mostly shallow to medium and deep black soils. This zone contributes about 60 % of the total cotton production of India. Rajasthan, which comes under North zone where climate is adverse at sowing season and the growing period, is limited to six months.

Growing area of Bt. cotton has increased 1.5 times in state and productivity of Bt. cotton is also almost double as compared to hybrid cotton. Owing to its high yielding nature, requirement of major and micronutrients are more. Therefore it is necessary to revisit the nutrient management in Bt. cotton.

Bt. or non Bt. hybrids have higher yield potential and demand more nutrients. Therefore, the fertilizer management of hybrid cotton enjoys a spectacular difference from that of conventional varieties. The cotton varieties have generally poor vegetative and reproductive growth than the hybrids. The hybrids have the potentiality to bear a higher leaf area per plant much earlier to varieties and require relatively higher

nutrition at early stages. Similarly, the hybrid cotton plant bears more fruiting points and has larger bolls. As the nutritional demands at various stages of growth of hybrid cotton can ultimately decide the cotton yields, a careful planning of schedule and quantity of fertilizers is needed in case of hybrid cotton.

In Bt. Cotton, nutrient management is the practice of soil fertility and health, sustaining agricultural productivity and improving farmers' profitability through the judicious and efficient use of mineral fertilizers along with organic manures, industrial/farm wastes and bio-fertilizers. The review of literature relating to effect of K, Mg and S on yield and quality as well as nutrient uptake is given under following headings.

2.1. Effects of K, Mg and S on growth and yield of cotton

2.2. Effects of K, Mg and S on nutrient status of plant and soil of cotton

2.1. Effects of K, Mg and S on growth and yield of cotton

Eweida *et al.* (1979) reported that seed cotton yield was significantly increased with the foliar application of 2 per cent

magnesium and 0.2 per cent zinc and also with combination of zinc sulphate and magnesium sulphate.

Namdeo *et al.* (1992) reported that the foliar application of Micnelf (1%) at 30, 65 and 90 days after sowing increased the number of bolls per plant but boll weight was increased by magnesium sulphate (2%) and Muriate of potash (2%) at 90 DAS. Micnelf (1%) at 30, 65 and 90 DAS gave significantly higher seed cotton yield than control, which was followed by magnesium sulphate (2%) at 30 and 60 DAS.

Prasad and Prasad (1994) observed that application of 80:40:20 kg NPK per hectare in combination with or without zinc sulphate, gypsum, borax, manganese sulphate or magnesium sulphate resulted in increased seed cotton yield, the highest yield being observed with NPK + Zn or Mg

Prasad and Prasad (1994) recorded significantly more number of bolls per plant (22.3), boll weight (4.8) and seed cotton yield (16.4 q ha⁻¹) than control (21.3, 4.7, 15.6 q ha⁻¹), respectively due to application of S @ 25 kg ha⁻¹.

A field study was conducted by Khandagave *et al.* (1996) at Agricultural Research Station, Dharwad to know the influence of soil application of elemental sulphur and zinc sulphate individually and in combination on cotton variety Abadhita under rainfed conditions. The

treatments comprised of 0, 20 and 40 S kg ha⁻¹ with or without 0, 25, and 50 kg ZnSO₄ ha⁻¹. Application of 25 kg ZnSO₄ ha⁻¹ significantly increased total dry matter, harvested bolls and seed cotton yield per plant and seed cotton yield ha⁻¹ over control, where as sulphur had no effect.

Pettigrew and Meredith (1997) reported that K fertilization resulted in more stem (21%), bur (13%), seed (19%), and lint weight (20%) than control and the plants received K fertilization also increased efficiency of fertilizer N use and of N utilization within the plant. The smaller LAI of the K deficient plants probably reduced the photosynthetic capacity per plant. A reduced assimilation capacity could explain the inefficiency of N use, lint yield reductions and poorer fiber quality was often associated with K deficiencies.

Sharma and Dungarwal (1997) conducted an experiment on cotton at Agricultural Research Station, Sriganganagar of Rajasthan Agricultural University, Rajasthan during two consecutive *kharif* seasons. The results revealed that application of sulphur at 50 kg ha⁻¹ increased the lint yield and lint index by 25.4 and 8.9 per cent over control, respectively.

Singh (1997) conducted field experiments on two different cotton cultivars *viz.* LRA-5166 and H-4 to study the response of sulphur and magnesium. Application of S at 20 kg ha⁻¹ to both LRA-5166 and H4 recorded maximum dry matter yield (35.0 and 24.0 g plant⁻¹) and plant height (86.0 and 92.5 cm), respectively and were significantly superior over control (18 g plant⁻¹, 73 cm).

Prasad (1998) conducted a field experiment at the Research Farm of Indian Agricultural Research Institute, New Delhi, to study the effect of nitrogen, phosphorus and sulphur requirement of cotton and *Gobhi* serson rotation. The results indicated that application of S @ 25 kg ha⁻¹ registered significantly higher yield (29 .0 q ha⁻¹) than control (28.2 q ha⁻¹). He further reported that due to addition of S @ 25 kg ha⁻¹ there was significant increase in plant height of upland cotton (147.1 cm) over control (144.5 cm) (Prasad, 2000).

Hanumanthareddy (1999) revealed that the foliar application of NAA in combination with MgSO₄ increased the number of monopodial and sympodial branches, number of good bolls per plant, average boll weight, seed weight per plant, number of seeds per boll and significantly the highest *kapas* yield was recorded in MgSO₄ (1%) in combination with NAA (10 ppm).

Sharma *et al.* (2000) conducted a field experiment at Hisar, Haryana on loamy sand sierozem soil for two years (1995 and 1996) and the results indicated that application of sulphur at 30 kg ha⁻¹ recorded the highest plant height (165.31 cm) which was significantly superior over control (146.21 cm). Similarly they have also reported that application of sulphur significantly increased the seed cotton yield by 3.11q ha⁻¹ over control. Sulphur at 30 kg ha⁻¹ gave maximum seed cotton yield (25.04 q ha⁻¹). Among the sources of sulphur, single superphosphate produced the maximum seed cotton yield (25.76 q ha⁻¹).

A field study was conducted by Dubey *et al.* (2000) to study the sulphur response in cotton and found that the foliar application of sulphur in the form of sodium sulphate application at 4 millimoles litre⁻¹ significantly increased the dry weight (185.3 g plant⁻¹) and it was on par with 2 millimoles litre⁻¹ (179.3g plant⁻¹) which were significantly superior over others.

Chatterjee *et al.* (2000) reported that the deficiency of sulphur reduced the concentration of chlorophyll, sugars, starch and protein in cotton leaves. The activity of ribonuclease decreased and that of catalase, peroxidase, acid phosphatase and starch reduced by low sulphur. As a result of sulphur deficiency the quality of cotton seeds deteriorated which

was reflected in low content of oil, sugars, starch, proteins and high concentration of phenols.

Dubey *et al.* (2000) conducted field experiment at Luknow to study the sulphur response in cotton. Sulphur was applied in the form of sodium sulphate @ 4 m moles litre⁻¹ which recorded significantly higher boll weight (58.0 g plant⁻¹), seed weight (28.5 g plant⁻¹), fiber weight (7.6 g plant⁻¹) than control (11.8 g plant⁻¹ 7.4 g plant⁻¹, 2.4 g plant⁻¹, 2.4 g plant⁻¹), respectively.

Muhammad *et al.* (2001) reported that application of gypsum @ 200 kg ha⁻¹ as a source of sulphur recorded significantly higher seed cotton yield (2215 kg ha⁻¹) than control (1981 kg ha⁻¹).

Makhdum *et al.* (2001) carried out studies in Multan, Pakistan, to evaluate the response of cotton to multi-nutrient superphosphate, SG 100 as a sulphur fertilizer under field conditions. The treatment consisted of 0, 125, 250, 375 and 500 kg multi-nutrient superphosphate SG 100 ha⁻¹ which was sufficient to overcome sulphur deficiency as well as for optimum cotton production in silt loam soils.

Singh and Kairon (2001) conducted a field experiment on sandy loam (*Inceptisol*) soil to study the effect of sulphur on cotton and sunflower during *kharif* and *rabi* seasons. The results revealed that yield of cotton and sunflower seed was increased with increase in sulphur

rates. Highest yield of cotton seed (1571 kg ha^{-1}) and sunflower seed (1114 kg ha^{-1}) was recorded with 30 S kg ha^{-1} application, which was 23.5 and 16.5 per cent higher than control, respectively.

Chhabra *et al.* (2004) reported that the application of recommended dose of N, P, K and S recorded significantly higher number of bolls per plant (22.73), yield per plant (65.36 g) and yield ($2024.3 \text{ kg ha}^{-1}$) than control (19.82, 52.51, 160, kg ha^{-1}), respectively.

Sharma and Kumawat (2005) conducted an experiment at Agricultural Research Station, Sriganganagar Rajasthan to study the effect of growth regulators, S fertilization and production potential of cotton. The results indicated that application of S @ 50 kg ha^{-1} remained on par with S @ 100 kg ha^{-1} and produced significantly 17.6 and 25.4 per cent higher cotton seed yield and lint yield than control, respectively.

Sawan *et al.* (2006) reported that the foliar application of potassium as potassium sulfate to cotton cultivar “Giza 86” significantly increased seed yield and the content of seed protein and oil, seed oil refractive index, unsaponifiable matter and total unsaturated fatty acids (oleic and linoleic) in Egyptian cotton.

There was a significant change in seed cotton yield due to different treatments comprising of K, Mg and S fertilizers. The improvement in

seed cotton yield was to the tune of 13.86, 5.20 and 26.67 % due to application of 90 kg K, 20 kg Mg and 40 S kg ha⁻¹, respectively over control (Anon., 2006-08).

Zakaria *et al.* (2008) observed that the seed cotton yield per plant and seed cotton and lint yield per ha were increased with the foliar application of 319 g K ha⁻¹ at 70 and 95 DAP.

Dunn *et al.* (2008) documented that an annual application of 22 kg S ha⁻¹ increased cotton lint yields by an average of 21% over 3 yr on a loamy sand soil in Alabama (USA), S application at pre-planting produced equal or better performance than S application at first square. Further they reported that cotton lint yields responded significantly to S fertilization on a fine sand soil but not on a silt loam soil.

Patel *et al.* (2010) conducted an experiment on clay soil at NAU, Surat, which indicated that the RDF based on soil test value + FYM 10 t ha⁻¹ + spray of 2% urea (at flowering) and one spray of 1 % urea + 1 % MgSO₄ during boll development stage increased seed cotton yield significantly over the control. Further, with respect to biochemical observations at Surat total chlorophyll content was found to be maximum under RDF treatment with the application of RDF STV + 10 FYM ha⁻¹ along with foliar spray of urea 19-19-19 at peak flowering to

boll development stage and 0.5 % ZnSO_4 as well as MgSO_4 -1.0% at different growth stage.

Sankaranarayan *et al.* (2010) carried out field experiment on clay loamy soil at the Regional station (CICR), Coimbatore (Tamil Nadu) and reported that the foliar sprays of MgSO_4 @ 0.5% at 60, 75 and 90 days after planting and soil applied borax @ 5 kg ha⁻¹ also raised the seed cotton yield.

The treatments which supplied all nutrients (NP-RDF, K-30%, Mg-10% and S-17%) at 1.5 times (150%) higher than that of recommended dose significantly increased seed cotton yield on loamy sand soils of Anand (Anon., 2010-11).

All India Co-ordinated Cotton Improvement Project has conducted experiments on Bt. cotton for optimization of N-P₂O₅-K₂O as well as nutrient management through organic and inorganic fertilizers at various locations viz. Rahuri, Khandwa, Nanded, Indore, Surat, Akola, Junagadh, Bhawanipatna, Coimbatore, Lam, Nandyal, Siruguppa, Dharwad, Indore, Khandwa, Faridakot, Ludhiana, Hisar, Sirsa and Sriganaganagar of the country (Anon., 2008-09). It was observed that 125 to 150 % RDF (N-P-K) is required for higher seed cotton yield. Further, it was also found that the foliar feeding of N, P, K, Mg, S and

micronutrients were also found beneficial to increase the seed cotton yield at various locations with conjunction with RDF. Similarly at Anand, 150% application of N and K in conjunction with S @ 40 kg ha⁻¹ significantly increased seed cotton yield on loamy sand soil (STCRC, M.P.K.V, Rahuri).

Among different treatments evaluated for amelioration of leaf reddening/parawilt of cotton, the spray of 2% urea + 2% DAP + 1% MgSO₄, or KNO₃ (1%) performed better than all other treatments in improving seed cotton yield (Anon., 2012).

All India Co-ordinated Cotton Improvement Project had conducted trails on foliar feeding of micronutrients to enhance seed cotton yield at various locations viz., Ludhiana, Faridkot, Bhatinda, Sriganaganagar, Nanded and Srivalliputhur. Foliar feeding trials on micronutrients showed that spraying of FeSO₄-0.5% at Bhatinda and MgSO₄-1.0% + ZnSO₄-0.5% at Faridkot, Ludhiana, Sriganaganagar, Nanded and Srivalliputhur gave significantly higher seed cotton yield over no spray (Anon., 2010-11).

At Anand, the foliar spray of 0.5% each of FeSO₄, ZnSO₄, MgSO₄ and urea at 30, 60 and 90 DAS along with RDF N (280 kg ha⁻¹) produced

significantly higher yield besides minimizing physiological disorders (Anon., 2011-12).

At Anand, pooled data of 4 years revealed that application of K_2O and $MgSO_4$ @ 100 kg ha⁻¹ and S @ 30 kg ha⁻¹ gave significantly higher seed cotton yield, stalk yield and K, Mg and S content (%) in cotton leaf on loamy sand soil than control (Anon., 2012-13).

2.2. Effects of K, Mg and S on nutrient status of plant and soil of cotton

The experiment on potassium fertilizer to cotton on low and medium K- status loess-derived soil were carried out by split application rates of K (0, 30, 60, 90, 120, 150 and 180 lb K_2O /ac) at different experimental station in USA. The results revealed that on low K testing soils more than 180 lb/ac K_2O is required for getting optimum yield of cotton, while in medium testing soil 110 lb/ac K_2O is required (Essington *et al.*, 2002).

Field trials were carried out to evaluate the effect of two levels of potassium and time of its application on the yield and yield components of cotton at Pakistan. during years 2001 and 2002. Potassium fertilizer was applied @ 131.25 and 162.50 kg ha⁻¹ i.e. (a) full dose at the time of sowing, (b) full dose at the time of first irrigation and (c) in split application i.e. half at the time of sowing and remaining half at the time

of first irrigation. These treatments were compared among themselves in addition to check treatments. Results showed that potassium fertilizer applied @ 131.25 kg ha⁻¹ at sowing produced maximum seed cotton yield during both the years. After harvest of cotton at 2nd year the potassium level was 187 kg ha⁻¹ significantly increased in soil over initial level (Kaleem *et al.*, 2009).

A field experiment was conducted on S deficient soil at Jackson in 2007-10 to evaluate cotton yield and fiber quality due to S application. Sulphur treatments of 0, 11, 22 and 34 kg S ha⁻¹ gave positive response in 3 out of 4 years. Leaf S concentration was increased by S application. Application of 22 or 34 kg S ha⁻¹ increased lint yield by 8 to 9 per cent average over three normal seasons (2008-2010) (Yin *et al.*, 2011)

A field experiment was conducted to study the response of K, Mg and S application on Bt. cotton at Anand during 2012. The results that K, Mg and content (%) in cotton leaf was increased significantly (0.84 %), (1.67 %) and (0.46 %) over control (0.74 %), (1.51 %) and (0.37 %) due to application of K and Mg @ 100 kg ha⁻¹ and S @ 30 kg ha⁻¹, respectively. The available potassium, exchangeable magnesium and available sulphur status were 273 kg ha⁻¹, 5.45 me 100 g⁻¹ soil and 7.7mg kg⁻¹ corresponding value in control were 215 kg ha⁻¹, 5.34 me 100 g⁻¹ soil and 6.6 mg kg⁻¹ (Anon., 2012-13).

III. MATERIALS AND METHODS

The details of the materials used, experimental methods followed and techniques adopted during the course of investigation are furnished below.

3.1 EXPERIMENTAL SITE

The present field experiment was conducted at Micronutrient Project (ICAR) experimental site, College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *kharif* season of the year 2012.

3.2 CLIMATE AND WEATHER CONDITION

Geographically, Anand is situated at 22° 35' N latitude, 72° 55' E longitudes with an elevation of 45.1 m above the mean sea level. The climate of this region is semi arid and sub tropical. Monsoon commences by the third week of June and retreats by middle of September with an average rainfall of 864 to 870 mm received entirely from the south west monsoon current. July and August are the months of heavy precipitation and there is no rainfall in winter and summer in almost all part of Gujarat. Except some sporadic showers in *Rabi* season, winter is severe

and sets in the month of November and continues till the end of January.

Summer is hot and dry, spread over for the months of April-May.

The observations on the meteorological parameters for the period of investigation, *kharif* season of the year 2012-2013 were recorded at the Meteorological Observatory of the Anand Agricultural University, Anand. According to the data represented in the Table 3.1., mean minimum temperature ranged from 12.6°C to 27.8°C, while mean maximum temperature ranged from 38.1°C to 29.2°C during the crop season of the year 2012-13. The other weather parameters *viz.*, average relative humidity, wind velocity and bright sunshine hours were also recorded during the experimental period. The unseasonal rainfall was not received during study period. In general, the weather conditions were found favourable for normal growth of cotton crop.

3.3 PHYSICO-CHEMICAL CHARACTERISTICS OF SOIL

The experimental field had an even topography with a good drainage. The soil is representative of the soils of the middle Gujarat region and is locally known as “Goradu” soil. The texture of the soil is loamy sand, very deep and moisture retentive belongs to the soil order Inceptisols (*Typic Ustochrept*). It responds well to manuring and is

suitable to variety of crops of tropical region. The ground water table is having more than 10 m. depth, posing no problem of higher water table in the area. The composite soil samples were collected from the experimental plot upto a depth of 15 cm before sowing of the crop and analyzed for important physical and chemical properties of soil, details of which are presented in Table 3.2.

Table 3.1: Mean weekly meteorological data recorded at the Meteorological Observatory, Anand Agricultural University, Anand for the crop season *kharif* 2012.

Month and Year	Std. Met. Week	Date	Temperature (°C)		Bright Sun shine hours day ⁻¹	Mean R.H. (%)	Evapo-ration (mm day ⁻¹)	Wind Speed (km hr ⁻¹)	Rain fall (mm)
			Max.	Min.					
June - July 2012	25	20-26	38.1	27.8	8.6	64.2	9.4	10.1	0.0
	26	27-3	37.5	27.9	9.5	63.5	9.2	9.7	2.6
July-2012	27	04-10	33.9	26.6	2.3	79.6	4.5	7.8	78.4
	28	11-17	32.6	25.9	4.7	85.3	4.8	6.5	129.8
	29	18-24	32.8	27.2	5.3	80.4	4.6	6.7	46.3
	30	25-31	32.8	26.6	0.9	81.5	4.3	7.2	2.2
August- 2012	31	01-07	31.6	26.3	1.2	80.6	4.4	7.4	5.2
	32	08-14	31.3	25.6	1.5	86	3.2	7.1	84.9
	33	15-21	29.9	24.8	2.4	88	2.5	6.4	191.4
	34	22-28	32.1	25.0	3.2	83.3	3.9	5.5	27.6
August- September- October 2012	35	29-04	32.4	25.7	3.2	89.1	3.4	3.6	176.2
	36	05-11	31.8	25.3	2.7	92.4	3.4	5.2	165.6
	37	12-18	30.0	25.0	1.3	90.8	2.6	5.7	47.9
	38	19-25	32.3	24.6	5.3	83.3	3.6	4.0	0.0
	39	26-02	32.8	23.8	8.0	75.7	3.7	3.2	5.0
October-	40	03-09	36.2	25.0	8.0	73.9	4.4	2.9	0.0
	41	10-16	36.1	20.7	8.8	66.5	4.6	2.1	0.0

November 2012	42	17-23	36.0	19.7	9.6	65.9	4.7	1.7	0.0
	43	24-30	35.3	18.8	9.8	58.3	4.6	1.8	0.0
	44	31-06	33.4	15.7	8.8	53.4	4.7	2.5	0.0
November- December 2012	45	07-13	32.6	13.9	9.6	57.8	3.7	1.8	0.0
	46	14-20	33.0	15.1	9.5	61.5	3.3	1.5	0.0
	47	21-27	31.4	12.6	9.3	60.7	3.3	1.6	0.0
	48	28-04	30.4	13.3	9.7	65.4	3.6	2.3	0.0
December 2012	49	05-11	31.3	16.1	8.5	63.4	2.9	2.0	0.0
	50	12-18	30.9	13.9	9.2	69.8	3.0	1.5	0.0
	51	19-25	29.2	13.9	8.6	66.4	3.3	2.9	0.0

The soil chemical analysis indicated that it was low in available nitrogen (100 kg ha^{-1}). It was medium in available phosphorus (31.8 kg ha^{-1}) as well as, available potash (238 kg ha^{-1}) and sufficient in available magnesium ($7.2 \text{ me } 100 \text{ g}^{-1}$ of soil) and low in available sulphur (5.7 mg kg^{-1}). Among micronutrient cations Zn (0.4 mg kg^{-1}) was deficient and Fe (6.6 mg kg^{-1}) as well as Mn (7.8 mg kg^{-1}) were medium, while Cu (1.23 mg kg^{-1}) status was high.

Table 3.2: Important physico-chemical properties of the soil of experimental field

Sr. No.	Properties	Initial value
Physical Properties		
1.	Mechanical analysis (International pipette method) (0-15 cm)	
	Clay (%)	9.8
	Silt (%)	7.2
	Fine sand (%)	82.3
	Coarse sand (%)	0.3
2.	Texture	Loamy sand
Chemical Properties		
3.	pH (1:2.5)	7.9
4.	EC (1:2.5) (dS m^{-1})	0.21
5.	Organic carbon (g kg^{-1})	4.3
	Available N (kg ha^{-1})	100

6.	Available P ₂ O ₅ (0.5 M NaHCO ₃ pH 8.5 extractable-P) (kg ha ⁻¹)	31.8
7.	Available K ₂ O (N NH ₄ OAc extractable) (kg ha ⁻¹)	238
8.	Available S (0.15 % CaCl ₂ extractable) (mg kg ⁻¹)	5.7
9.	Available Mg (N NH ₄ OAc extractable) (me 100 g ⁻¹ of soil)	7.2
10.	Micronutrients (0.005 M DTPA-extractable) (mg kg ⁻¹)	
	Fe	6.6
	Mn	7.8
	Zn	0.4
	Cu	1.23

3.4 EXPERIMENTAL DETAILS

The details of experimental techniques and layout employed for the investigation are described as under.

3.4.1 Experimental design and layout

1. **Crop** : Bt. Cotton
2. **Variety** : Bijadhan-2 (Bollgard-II)
3. **Year and Season** : *Kharif* 2012-2013
4. **Design** : Factorial randomized Block Design
(FRBD) (3 Factor)
 - a) Treatments : 8 (Eight)
 - b) Replications : 4 (four)
 - c) No. of plots : 8 X 4 = 32
5. **Plot size**

I. Gross plot size : 6.3 x 4.8 m

II. Net plot size : 5.4 x 2.4 m

6. Spacing : 120 x 45 cm

7. Seed Rate : 1.5 kg ha⁻¹

8. Fertilizer : Nitrogen @
280 kg ha⁻¹ in four equal splits, no
P, no organic manure. Potassium,
magnesium and sulphur as per
treatments.

3.4.2 Treatment details

Total 8 treatments were included in the present investigation with different levels of K, Mg and S. The treatment combination details are given in Table 3.3.

(A) K₂O levels (kg ha⁻¹): Two (Source – MOP)

(1) 0

(2) 120

(B) S levels (kg ha⁻¹): Two (Source – Gypsum)_____

(1) 0

(2) 40

(C) Mg O levels (kg ha⁻¹): Two (Source – MgO)

(1) 0

(2) 40

3.5 OTHER CULTURAL OPERATIONS

3.5.1 Field Preparation

The experimental field was thoroughly prepared by tractor driven cultivator followed by harrowing and at last planking for leveling the soil. After field preparation, plots were laid out accordingly as mentioned in the layout details. The sequence of operations carried out in the field

during the course of investigation is outlined in Table 3.4.

3.5.2 Application of fertilizers

The lines were drawn by marker in each plot keeping spacing of 120 x 45 cm in between two rows. Full dose of 280 kg N ha⁻¹ (in 4 equal splits) and K, Mg, and S applied was made according to the treatments the details are given in Table 3.3.

3.5.3 Sowing of the crop

The seeds of Bt. Cotton were sown at optimum depth at a common row spacing of 120 x 45 cm. Sowing was performed under dry condition and the seeds were covered with the soil manually.

Table 3.3: Treatment combinations: 08

	Treatments denotation	K₂O	MgO	S
	K ₀ Mg ₀ S ₀	00	00	00
	K ₀ Mg ₀ S ₄₀	00	00	40
	K ₀ Mg ₄₀ S ₀	00	40	00
	K ₀ Mg ₄₀ S ₄₀	00	40	40
	K ₁₂₀ Mg ₀ S ₀	120	00	00
	K ₁₂₀ Mg ₀ S ₄₀	120	00	40
	K ₁₂₀ Mg ₄₀ S ₀	120	40	00
	K ₁₂₀ Mg ₄₀ S ₄₀	120	40	40

3.6 POST SOWING OPERATIONS

3.6.1 Irrigation

Bt. Cotton crop is very sensitive to moisture stress. In order to maintain moisture availability to the crop throughout the growth period four irrigations were given. First irrigation was given immediately after sowing, followed by successive three irrigations as mention in table 3.3.

Table 3.4: Calendar of the operations carried out during the experimental period

Sr. No.	Operations	Frequency	Date
Pre sowing			
1.	Soil Sampling (Initial)	One	13/06/2012
2.	Field preparation (Tractor cultivation)	One	15/06/2012
3.	Field lay out	One	18/06/2012
4.	Application of basal dose of fertilizers	One	21/06/2012
Sowing and post sowing			
6.	Sowing	One	21/06/2012
7.	Soil and leaf Sampling		
	30DAS	One	22/07/2012
	60 DAS	One	22/08/2012
	90 DAS	One	22/09/2012
8.	Irrigations		
	a. First irrigation (after sowing)	One	22/06/2012
	b. Second irrigation	One	28/06/2012
	c. Third irrigation	One	23/08/2012
	d. Fourth irrigation	One	06/10/2012
8.	Weeding		
	a. First Weeding	One	08/07/2012
	b. Second Weeding	One	27/07/2012

	c. Third Weeding	One	11/10/2012
9.	Plant protection		
	Chlorpyrifos (drenching)	One	23/07/2012
	Monocrotophos (spray)	One	20/08/2012
	Imidacloprid (spray)	One	15/09/2012
10.	Plant height		
	30DAS	One	21/07/2012
	60 DAS	One	21/08/2012
	90 DAS	One	21/09/2012
	At harvest	One	19/12/2012
11.	Plant stand at harvest	One	19/12/2012
12.	Cotton picking		
	a. First picking	One	17/10/2012
	b. Second picking	One	31/10/2012
	c. Third picking	One	20/11/2012
	d. Fourth picking	One	18/12/2012
13.	Removal of root and stalk (Uprooting of plant)	One	19/12/2012
14.	Plant sampling (after harvest)	One	19/12/2012
15.	Soil Sampling (after Harvest)	One	19/12/2012

3.6.2 Weeding

Three manual weeding were performed at 17, 36 and 112 DAS to remove the weeds from the experimental plot.

3.6.3 Plant height

The plant height was measured at 30, 60, 90 DAS and at harvest. The plant height was measured from ground level to the tip of the main stem on five randomly selected and tagged plants at 30, 60, 90 DAS and at harvest and average height was computed and expressed in cm.

3.6.4 Plant protection

The chlorpyrifos (40 mL/10 L.) was drenched around the plant to control the infestation of termite. Monocrotophos (15 mL/10 L.) was applied as spray as and when required to control the infestation of sucking pests after 30 DAS. And also Imidacloprid (7 mL/10 L.) was applied as spray as and when required to control the infestation of sucking pests after 60 DAS.

3.6.5 Plant stand at harvest

The total no. of plants was recorded in each experiment plot at harvest in 30.24 m² areas and the uniform plant stand was maintained at the beginning by gap filling of plant raised in polythene bags.

3.6.6 Oil content in seed

The analysis of oil content of cotton seed was carried out by using Soxhlet oil extraction method.

3.6.7 Harvesting

The picking was done as and when required i.e. first, second and third picking was done on 17/10/2012, 31/10/2012 and 20/11/2012 respectively. At last the crop was uprooted immediately after fourth picking. The harvested seed cotton was weighed just after picking on 19/12/2013.

3.7 SAMPLE COLLECTION AND PROCESSING

3.7.1 Soil sampling

The soil samples from individual treatment were (0-15 cm)

collected from four spots in each plot randomly and mixed thoroughly and a composite sample was prepared. The soil samples were air-dried and ground to pass through a 2 mm sieve. The samples were stored in polythene lined cotton bags for further analysis.

3.7.2 Plant sampling

Treatment-wise representative leaf samples were collected from each plot after harvest of the crop for analysis. The samples were washed with dilute 0.03 N HCl, single and double deionized water in a sequence and air dried. Then samples were dried in paper bags at 70°C till constant weight in a hot air oven and preserved for further analysis. These samples were ground in a stainless steel Wiley mill to avoid contamination of micronutrients. The processed samples were preserved in airtight polyethylene bags for further analysis.

3.8 METHODS OF ANALYSIS

3.8.1 Yield and yield attributes

3.8.1.1 Cotton yield (kg ha⁻¹)

The produce of each net plot and each cotton picking separately, cleaned and the seed cotton yield was recorded in kg per net plot and then converted into kg ha⁻¹.

3.8.1.2 Seed yield (kg ha⁻¹)

The produce of each net plot was picked separately, cleaned and the seed cotton yield was recorded in kg per net plot and then converted into kg ha⁻¹.

3.8.1.3 Stalk yield (kg ha⁻¹)

The uprooted plants were allowed to dry in field. Treatment wise yield was recorded and was computed on hectare basis. The dry weight of stalk was expressed in kg ha⁻¹.

3.8.1 Soil analysis

The processed soil samples were analyzed initially and after completion of the experiment, for important soil properties *viz.* pH, EC (1:2.5; soil: water ratio), organic carbon (OC), available nutrients *viz.*, P, K, S, Mg and DTPA (Diethyleme Triamine Penta Acetic Acid) extractable micronutrients (Zn, Fe, Mn and Cu) as per the standard methods (Table 3.5).

Table 3.5: Methods used for soil analysis

Sr. No.	Parameters	Extraction method	Reference
1.	pH (1:2.5 soil: water)	Potentiometric	Jackson (1973)
2.	EC (1:2.5 soil: water)	Conductometric	Jackson (1973)
3.	Organic carbon (OC)	Walkley Black's wet oxidation method	Jackson (1973)
4.	Available N	Alkaline KMnO ₄ (0.32%) method	Subbiah and Asija (1956)
5.	Available P ₂ O ₅	0.5 M NaHCO ₃ , pH 8.5,	Olsen <i>et al.</i> (1954)

		Spectrophotometry	
6.	Available K ₂ O	1N NH ₄ OAc pH 7.0 (Flame photometric)	Jackson (1973)
7.	Available sulphur	Turbidimetric method (0.15 % CaCl ₂)	Chaudhary and Cornfield (1966)
8.	Available magnesium	Versenate method	Cheng and Bray (1951)
9.	Available micronutrients	0.005M DTPA (pH 7.3) (Atomic Absorption Spectrophotometry)	Lindsay and Norvell (1978)

3.8.2 Plant analysis

Dried plant samples (leaf and stalk) were ground in a stainless steel mixture. The lint and seed were separated manually and seed was crushed by using mortar and pestle. These were digested in di-acid mixture (HNO₃: HClO₄ – 4:1) and volume was made with double distilled water (Jackson, 1979). The extract was filtered through Whatman filter paper No. 42. The digested extract of plant samples was used for analysis of K, Mg and S as per standard procedure and micronutrients on atomic absorption spectrophotometer (AAS Model: PE 3110).

Table 3.6: Methods used for plant analysis

Sr. No.	Parameters	Extraction method	Reference
1.	Phosphors	Vanadomolybde	Jackson (1973)
2.	Potassium	1N NH ₄ OAC pH 7.0 (Flame photometric)	Jackson (1973)
3.	Sulphur	Turbidimetric method	Chaudhary and Cornfield (1966)
4.	Magnesium	Versenate method	Cheng and Bray (1951)
5.	Micronutrients	0.005M DTPA (pH 7.3) (Atomic Absorption Spectrophotometry)	Lindsay and Norvell (1978)

3.9 NUTRIENT ACCUMULATION

Nutrient accumulation per plant was calculated using nutrient content (%) and yield (g plant⁻¹).

$$\text{Nutrient accumulation (g plant}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (g plant}^{-1}\text{)}}{100}$$

3.10 STATISTICAL ANALYSIS

The data on dry matter yield, nutrient concentration and nutrient uptake by Bt. Cotton were subjected to statistical analysis as per the methods suggested by Steel and Torrie (2006) using computer facility of

the Micronutrient Project (ICAR), Anand Agricultural University, Anand. The standard error of mean (S.Em.) and critical difference (C.D.) at 5 per cent level of probability were worked out and presented in respective tables.

IV. EXPERIMENTAL RESULTS

The results obtained from the present investigation on “Effects of K, Mg and S fertilizers on growth and yield of Bt. cotton grown on loamy sand soil of middle Gujarat” are presented in this chapter. The data pertaining to the growth and yield attributes, yield, quality and chemical parameters were subjected to statistical analysis for the test of significance. The data for all the main effects of potassium, magnesium and sulphur fertilizer levels and only significant interactions are presented in the succeeding paragraphs. The results obtained in the present investigation are presented here under following heads:

4.1. EFFECT ON GROWTH

4.2. EFFECT ON YIELD

4.3. EFFECT ON NUTRIENT CONTENT IN PLANT

4.4. NUTRIENT ACCUMULATION BY PLANT

4.5. EFFECT ON IMPORTANT PHYSICO-CHEMICAL PROPERTIES OF SOIL

4.1. EFFECT ON GROWTH

4.1.1. Plant stand at harvest

Data reported in Table 4.1 represent the No. of plant per 30.24 m² at harvest of Bt. cotton as affected due to application of potassium, magnesium and sulphur fertilizer levels.

□.....
*Experimental results*

The plant stand was altered significantly due to individual application of K and S at harvest. The individual application of 120 kg K ha⁻¹ and S @ 40 kg ha⁻¹ maintained significantly higher plant stand (45.5 and 42.7) as compared to respective controls (41.6 and 41.7). There was good effect of Mg₄₀ also to maintained plant stand over Mg₀, but it did not reach to the level of significance.

Table 4.1: Effect of different levels of K, Mg and S fertilizers application on plant stand at harvest of Bt. cotton

Treatments	Plant stand at harvest (30.24 m²)
K₀	41.6
K₁₂₀	45.4
S. Em.±	0.9
C.D. at 5%	2.5
Mg₀	42.7
Mg₄₀	44.2
S. Em.±	0.9
C.D. at 5%	NS
S₀	41.7
S₄₀	46.0
S. Em.±	0.9
C.D. at 5%	2.5
Interaction Effect	
K X M	NS
K X S	NS
M X S	NS
K X M X S	NS
C.V. %	8.0

4.1.2. Plant height (cm)

Data on plant height (cm) recorded at 30, 60, 90 DAS and at harvest are presented in Table 4.2.

The differences in plant height were non-significant in all the cases except K X Mg interaction, wherein significantly the highest plant height (93.9 cm) was noticed under no potassium and no magnesium (K_0Mg_0) treatment at harvest.

Table 4.2: Effect of different levels of K, Mg and S fertilizers application on plant height at different stages of Bt. cotton

Treatment s	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At har ves t
K_0	11.3	29.7	72.6	90.6
K_{120}	11.7	29.0	72.7	87.3
S. Em.±	0.20	0.6	1.0	1.0
C.D. at 5%	NS	NS	NS	NS
Mg_0	11.3	29.5	72.8	89.7
Mg_{40}	11.7	29.3	72.6	88.2
S. Em.±	0.20	0.63	1.0	1.0
C.D. at 5%	NS	NS	NS	NS
S_0	11.1	29.0	74.1	88.3
S_{40}	11.7	29.7	74.2	89.6
S. Em.±	0.20	0.63	1.01	1.04
C.D. at 5%	NS	NS	NS	NS
Interaction Effect				
K X M	NS	NS	NS	Sig.
K X S	NS	NS	NS	NS
M X S	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS
C.V. %	7.7	8.5	5.5	4.7

□.....
Experimental results

Table 4.3: Interaction effect of different levels of K and Mg fertilizers application on plant height (cm) of Bt. cotton at harvest

Potassium x magnesium		
K levels	K ₀	K ₁₂₀
Mg levels		
Mg ₀	93.9	85.5
Mg ₄₀	87.3	89.1
C.D. at 5% = 4.3		

4.2. EFFECT ON YIELD

The data of seed cotton yield, stalk yield and oil content are presented in Table 4.3.

4.2.1. Seed cotton yield

Seed cotton yield was affected significantly due to application of K @ 120 kg ha⁻¹ (1356 kg ha⁻¹) over its control (1204 kg ha⁻¹) as well as due to S @ 40 kg ha⁻¹ (1420 kg ha⁻¹) over no S (1140 kg ha⁻¹) application. Whereas the effect of Mg was non-significant. The improvement in seed cotton yield due to K, Mg and S was to the tune of 12.6, 0.8 and 24.6 per cent over respective control (Table 4.4 and also depicted in Fig. 1).

Potassium and sulphur (K X S) interaction indicated that the significantly the highest (1557 kg ha⁻¹) seed cotton yield was noticed due to combined effect of K₁₂₀ S₄₀. (Table 4.5)

4.2.2. Stalk yield

□.....
*Experimental results*

In case of stalk yield, the application of either K, Mg or S were significant over their respective controls. The improvement in stalk yield due to K₁₂₀, Mg₄₀ and S₄₀ was to the tune of 48.6, 18.9 and 19.3 per cent over respective control (Table 4.4 and also depicted in Fig. 2).

4.2.3. Oil content (%)

Among K, Mg and S application only S @ 40 kg ha⁻¹ improved oil content (19.8 %) significantly over no S (17.1 %). The improvement in oil content was to the tune of 15.8 per cent over control (S₀) (Table 4.4).

Table 4.4: Effect of different levels of K, Mg and S fertilizers application on Seed cotton, stalk yield and oil content of Bt. Cotton

Treatment s	Seed cotton yield (kg ha⁻¹)	Stalk yield (kg ha⁻¹)	Oil content (%)
K₀	1204	942	18.3
K₁₂₀	1356	1400	18.6
S. Em.±	41	43	0.3
C.D. at 5%	120	127	NS
M₀	1230	1070	18.0
M₄₀	1330	1272	18.4
S. Em.±	41	43	0.3
C.D. at 5%	NS	127	NS
S₀	1140	1068	17.1
S₄₀	1420	1275	19.8
S. Em.±	41	43	0.3
C.D. at 5%	120	127	0.9
Interaction Effect			
K X M	NS	NS	NS
K X S	Sig.	NS	NS
M X S	NS	NS	NS
K X M X S	NS	NS	NS

Table 4.5: Interaction effect of different levels of K and Mg fertilizers application on seed cotton yield (kg ha⁻¹) of Bt. cotton

Potassium x magnesium		
K levels	K₀	K₁₂₀
S levels		
S₀	1124	1156
S₄₀	1283	1557
C.D. at 5% = 169		

4.3. EFFECT ON NUTRIENT CONTENT IN PLANT

4.3.1 Effect on nutrient content in leaf of Bt. cotton at 30, 60 and 90 DAS

4.3.1.1. Total K (%)

The cotton leaf concentration of K was determined at 30, 60 and 90 DAS (Table 4.6).

In lower leaves, the overall K concentration varied from 0.33 to 0.38 % at 90 and 30 DAS, respectively, while in case of upper leaves, it ranged between 0.67 to 0.82 % during 90 and 30 DAS, respectively.

Table 4.6: Effect of different levels of K, Mg and S fertilizers

application on total K content in upper and lower leaf

at 30, 60 and 90 DAS of Bt. cotton

Treatment s	Total K (%)					
	Lower leaf			Upper leaf		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
K₀Mg₀S₀	0.37	0.38	0.27	0.74	0.74	0.66
K₀Mg₀S₄₀	0.38	0.36	0.39	0.80	0.74	0.61
K₀Mg₄₀S₀	0.37	0.33	0.34	0.78	0.72	0.66
K₀Mg₄₀S₄₀	0.40	0.36	0.33	0.77	0.79	0.63
K₁₂₀Mg₀S₀	0.33	0.38	0.31	0.85	0.88	0.76
K₁₂₀Mg₀S₄₀	0.37	0.37	0.32	0.86	0.65	0.73
K₁₂₀Mg₄₀S₀	0.37	0.36	0.33	0.89	0.8	0.66
K₁₂₀Mg₄₀S₄₀	0.42	0.33	0.38	0.84	0.83	0.67
Minimum	0.33	0.33	0.27	0.74	0.65	0.61
Maximum	0.42	0.38	0.39	0.89	0.88	0.76
Mean	0.38	0.36	0.33	0.82	0.77	0.67

4.3.1.2. Total Mg (%)

The cotton leaf concentration of Mg was determined at 30, 60 and 90 DAS and data are presented in Table 4.7.

The overall Mg concentration in lower leaf of Bt. cotton at 30, 60 and 90 DAS was analyzed and found to be 3.21, 3.11 and 2.55 % respectively. The corresponding Mg content in upper leaf was 2.87, 3.02 and 2.48 % during 30, 60 and 90 DAS of Bt. cotton.

□.....
Experimental results

Table 4.7: Effect of different levels of K, Mg and S fertilizers application on total Mg content in upper and lower leaf at 30, 60 and 90 DAS of Bt. cotton

Treatments	Total Mg (%)					
	Lower leaf			Upper leaf		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
K₀Mg₀S₀	3.03	2.53	2.28	2.83	3.13	2.18
K₀Mg₀S₄₀	3.03	2.73	2.18	2.83	2.80	2.28
K₀Mg₄₀S₀	3.83	3.39	2.98	3.03	3.09	2.47
K₀Mg₄₀S₄₀	3.73	3.59	2.48	2.93	3.19	2.98
K₁₂₀Mg₀S₀	2.83	2.89	2.64	2.73	2.79	2.24
K₁₂₀Mg₀S₄₀	2.21	3.29	2.54	2.73	3.19	2.54
K₁₂₀Mg₄₀S₀	3.43	3.09	2.64	3.03	2.69	2.64
K₁₂₀Mg₄₀S₄₀	3.63	3.38	2.64	2.83	3.28	2.54
Minimum	2.21	2.53	2.18	2.73	2.69	2.18
Maximum	3.83	3.59	2.98	3.03	3.28	2.98
Mean	3.21	3.11	2.55	2.87	3.02	2.48

4.3.1.3. Total S (%)

The concentration of S in cotton leaf was determined at 30, 60 and 90 DAS and data are presented in Table 4.8.

The S content in lower leaf was 0.88, 0.88 and 0.79 %, while it was 0.40, 0.40 and 0.32 % in case of upper leaves of Bt. cotton, at 30, 60 and 90 DAS, respectively.

Treatments	Total S (%)					
	Lower leaf			Upper leaf		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
K₀Mg₀S₀	0.80	0.83	0.77	0.39	0.33	0.29
K₀Mg₀S₄₀	0.84	0.81	0.7	0.44	0.42	0.34

.....Experimental results

K₀Mg₄₀S₀	0.81	0.81	0.78	0.34	0.36	0.23
K₀Mg₄₀S₄₀	0.79	0.81	0.72	0.43	0.4	0.24
K₁₂₀Mg₀S₀	0.92	0.98	0.85	0.36	0.39	0.37
K₁₂₀Mg₀S₄₀	0.97	0.97	0.86	0.45	0.42	0.37
K₁₂₀Mg₄₀S₀	0.98	0.95	0.81	0.32	0.38	0.34
K₁₂₀Mg₄₀S₄₀	0.96	0.91	0.85	0.45	0.47	0.34
Minimum	0.79	0.81	0.7	0.32	0.33	0.23
Maximum	0.98	0.98	0.86	0.45	0.47	0.37
Mean	0.88	0.88	0.79	0.40	0.40	0.32

Table 4.8: Effect of different levels of K, Mg and S fertilizers application on total S content in upper and lower leaf at 30, 60 and 90 DAS of Bt. cotton

4.3.2.1. Phosphorus content (%) in stalk, leaf, lint and seed

A perusal of data presented in Table 4.9 reveal that phosphorus content (%) in stalk, leaf, lint and seed was not affected significantly due to application of potassium, magnesium and sulphur fertilizer at harvest of Bt. Cotton.

Among different components seed contained the highest amount of P and it ranged from 0.33 to 0.37 per cent. Absence of K (K₀) and (S₀) registered higher (0.37 %) P content in seed.

Table 4.9: Effect of different levels of K, Mg and S fertilizers application on P content stalk, leaf, lint and seed of Bt. cotton

□.....

.....*Experimental results*

Treatments	P (%)			
	Stalk	Leaf	Lint	Seed
K₀	0.09	0.11	0.05	0.37
K₁₂₀	0.10	0.10	0.04	0.33
S. Em.±	0.005	0.01	0.002	0.01
C.D. at 5%	NS	NS	NS	NS
Mg₀	0.09	0.11	0.05	0.35
Mg₄₀	0.09	0.10	0.05	0.35
S. Em.±	0.005	0.01	0.002	0.01
C.D. at 5%	NS	NS	NS	NS
S₀	0.08	0.10	0.05	0.37
S₄₀	0.10	0.11	0.05	0.34
S. Em.±	0.005	0.01	0.002	0.01
C.D. at 5%	NS	NS	NS	NS
Interaction Effect				
K X M	NS	NS	NS	NS
K X S	NS	NS	NS	NS
M X S	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS
C.V. %	13.6	18.9	17.9	15.8

4.3.2.2. Potassium content (%) in stalk, leaf, lint and seed

Data presented in Table 4.10 revealed that potassium content (%) in stalk, leaf, lint and seed was not affected significantly due to application of potassium, magnesium and sulphur fertilizer levels at harvest of Bt. cotton, except K content of leaf. Application of K₁₂₀ kg ha⁻¹ gave significantly higher K content (0.73 %) in cotton leaf as compared to K₀ level (0.65 %). The increase in K content of leaf under K₁₂₀ was to the tune of 10.96 per cent over K₀.

The interaction effect of K, Mg and S was also non-significant for K content of different components of Bt. cotton.

Table 4.10: Effect of different levels of K, Mg and S fertilizers application on K content in stalk, leaf, lint and seed of Bt. cotton

Treatments	K (%)			
	Stalk	Leaf	Lint	Seed
K₀	0.04	0.65	0.13	0.53
K₁₂₀	0.18	0.73	0.24	0.54
S. Em.±	0.005	0.018	0.007	0.007
C.D. at 5%	NS	0.05	NS	NS
Mg₀	0.10	0.67	0.19	0.53
Mg₄₀	0.12	0.70	0.17	0.53
S. Em.±	0.005	0.018	0.007	0.007
C.D. at 5%	NS	NS	NS	NS
S₀	0.11	0.67	0.18	0.52
S₄₀	0.11	0.71	0.18	0.54
S. Em.±	0.005	0.018	0.007	0.007
C.D. at 5%	NS	NS	NS	NS
Interaction Effect				
K X M	NS	NS	NS	NS
K X S	NS	NS	NS	NS
M X S	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS
C.V. %	17.5	10.6	14.9	5.3

4.3.2.3. Magnesium content (%) in stalk, leaf, lint and seed

The data presented in Table 4.11 revealed that magnesium content (%) in stalk, leaf, lint and seed was not affected significantly due to application of potassium, magnesium and sulphur fertilizer levels at harvest of Bt. cotton except leaf content of Mg due to Mg application.

The significantly higher Mg content (3.0 %) in stalk and in leaf (3.0 %) was noticed due to Mg application @ 40 kg ha⁻¹ as compared to

□.....

.....Experimental results

control in stalk (1.9 %) and in leaf (2.3 %). The increase in Mg content of stalk and leaf was 36.67 and 23.34 per cent over respective controls.

The interaction effect of K, Mg and S on Mg content of different components was non-significant.

Table 4.11: Effect of different levels of K, Mg and S fertilizers application on Mg content in stalk, leaf, lint and seed of Bt. Cotton

Treatments	Mg (%)			
	Stalk	Leaf	Lint	Seed
K₀	2.3	2.6	0.2	1.8
K₁₂₀	2.6	2.7	0.2	2.2
S. Em.±	0.2	0.1	0.006	0.08
C.D. at 5%	NS	NS	NS	NS
Mg₀	1.9	2.3	0.2	1.8
Mg₄₀	3.0	3.0	0.2	2.2
S. Em.±	0.2	0.1	0.006	0.08
C.D. at 5%	0.6	0.4	NS	NS
S₀	2.6	2.7	0.2	2.0
S₄₀	2.3	2.6	0.2	1.9
S. Em.±	0.2	0.1	0.006	0.08
C.D. at 5%	NS	NS	NS	NS
Interaction effect				
K X M	NS	NS	NS	NS
K X S	NS	NS	NS	NS
M X S	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS
C.V. %	30.6	18.3	13.0	15.8

4.3.2.4. Sulphur content (%) in stalk, leaf, lint and seed

The data presented in Table 4.12 indicate that sulphur content (%) in stalk, leaf, lint and seed was not affected significantly due to

□.....

.....Experimental results

application of potassium, magnesium and sulphur fertilizer levels at harvest of Bt. Cotton except its content in leaf due to S application.

The S content in cotton leaf was increased significantly due to 40 kg S ha⁻¹ (0.29 %) over no S application (0.26%). The increase in S content under S₄₀ was to the extent of 3.33 per cent over S₀ level.

The interaction effect of K, Mg and S was also non-significant with respect to S content of different components of Bt. cotton.

Table 4.12: Effect of different levels of K, Mg and S fertilizers application on S content in stalk, leaf, lint and seed of Bt. cotton

Treatments	S (%)			
	Stalk	Leaf	Lint (ppm)	Seed (ppm)
K₀	0.07	0.27	56.1	979.4
K₁₂₀	0.06	0.29	51.2	938.9
S. Em.±	0.004	0.01	3.2	32.63
C.D. at 5%	NS	NS	NS	NS
Mg₀	0.06	0.28	53.7	923.7
Mg₄₀	0.06	0.28	53.6	994.6
S. Em.±	0.004	0.01	3.2	32.63
C.D. at 5%	NS	NS	NS	NS
S₀	0.06	0.26	50.3	934.8
S₄₀	0.07	0.30	56.9	983.5
S. Em.±	0.01	0.01	3.2	32.63
C.D. at 5%	NS	0.04	NS	NS
Interaction Effect				
K X M	NS	NS	NS	NS
K X S	NS	NS	NS	NS
M X S	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS
C.V. %	25.9	11.5	24.2	13.6

4.3.2.5. Micronutrients concentration (ppm) in plant

A data given in Table 4.13 and 4.14 revealed that the Fe, Mn Zn and Cu concentration (ppm) in stalk, leaf, lint and seed was not affected significantly due to application of potassium, magnesium and sulphur fertilizer levels at harvest of Bt. cotton except Cu content of leaf due to application of sulphur. The Cu content of leaf was significantly higher under S_{40} than S_0 level. The improvement in leaf Cu content due to S_{40} over S_0 was 5.0 per cent.

□.....
.....*Experimental results*

4.4 NUTRIENT ACCUMULATION BY PLANT

Data with regard to K, Mg and S nutrient accumulation (g plant⁻¹) at harvest in Bt. cotton are presented in Table 4.15.

The application of K, Mg and S significantly influenced the accumulation of K, Mg and S in plant except accumulation of Mg and S due to application of S and K, respectively. Application of K₁₂₀ significantly improved K accumulation over K₀. The Mg application of Mg₄₀ also significantly gave higher accumulation of K and Mg both over Mg₀ and sulphur addition at S₄₀ also improved Mg and S accumulation over S₀.

Among different interaction effect K X S was significant for accumulation K, K X S as well as M X S was significant for S

□.....

.....*Experimental results*

accumulation and higher order interaction K X M X S was significant for Mg accumulation.

Table 4.15: Effect of different levels of K, Mg and S fertilizers application on nutrient accumulation (g plant⁻¹) at harvest of Bt. cotton

Treatments	K	Mg	S
K₀	0.29	2.7	0.07
K₁₂₀	0.46	3.1	0.08
S. Em.±	0.01	0.1	0.005
C.D. at 5%	0.04	0.3	NS
Mg₀	0.35	2.0	0.07
Mg₄₀	0.40	3.2	0.08
S. Em.±	0.01	0.1	0.005
C.D. at 5%	0.04	0.3	0.01
S₀	0.33	2.5	0.07
S₄₀	0.42	2.7	0.09
S. Em.±	0.01	0.1	0.005
C.D. at 5%	0.04	NS	0.01
Interaction table			
K X M	NS	NS	NS
K X S	Sig.	NS	Sig.
M X S	NS	NS	Sig.
K X M X S	NS	Sig.	NS
CV %	4.3	17.2	24.9

Interaction effect of K X S for K accumulation:

The data presented in Table 4.16 show that interaction effect of K X S was significant for accumulation of K.

The significantly higher K accumulation (g plant⁻¹) was recorded due to either individual application of S or K as well as under combined application of S and K.

□.....
*Experimental results*

The maximum K accumulation ($0.536 \text{ g plant}^{-1}$) was noticed in the combined application of $K_{120} \times S_{40}$ which differed significantly from rest of the combinations.

Table 4.16: Interaction effect of different levels of K and S fertilizers application on K accumulation (g plant^{-1}) of Bt. cotton

Potassium x sulphur		
K levels	K_0	K_{120}
K levels		
S_0	0.266	0.387
S_{40}	0.310	0.536
C.D. at 5% = 0.055		

Interaction effect of K X S on S accumulation:

The data presented in Table 4.17 indicated that the interaction effect of K X S was significant for accumulation of S g plant^{-1} of Bt. cotton.

The highest S accumulation ($0.090 \text{ g plant}^{-1}$) was noticed under treatment combination $K_0 S_{40}$, however it was at par with treatment combination $K_{120} S_{40}$, which recorded S accumulation of 0.80 and $0.70 \text{ g plant}^{-1}$, respectively.

Table 4.17: Interaction effect of different levels of K and S fertilizers application on S accumulation (g plant⁻¹) of Bt. cotton at harvest

Potassium x sulphur		
K levels	K₀	K₁₂₀
S levels		
S₀	0.056	0.079
S₄₀	0.090	0.080
C.D. at 5% = 0.019		

Interaction effect of Mg X S on S accumulation:

The data presented in Table 4.18 indicated that the interaction effect of S X Mg was significant for accumulation of S in Bt. cotton plant.

The highest S accumulation (0.086 g plant⁻¹) was noticed under S₄₀ X Mg₄₀ due to combined application of Mg @ 40 kg ha⁻¹ and S @ 40 kg ha⁻¹, however it was on par with treatment combination S₄₀ Mg₀ and S₀ Mg₄₀, which registered S accumulation of 0.084 and 0.082 g plant⁻¹, respectively.

Table 4.18: Interaction effect of different levels of S and Mg fertilizers application on S accumulation (g plant⁻¹) of Bt. cotton at harvest

Sulphur x magnesium		
M levels	Mg₀	Mg₄₀
S levels		
S₀	0.053	0.082
S₄₀	0.084	0.086
Mean	0.068	0.083
C.D. at 5% = 0.019		

Interaction effect of K X Mg X S for Mg accumulation:

The data on interaction effect of K X Mg X S on Mg accumulation are given in Table 4.19.

The data revealed significant improvement was noticed due to different combinations except K₀ Mg₀ S₄₀ over control. The highest Mg accumulation (3.92 g plant⁻¹) was noticed under K₁₂₀ X Mg₄₀ X S₀ combination, which differed significantly from the rest combination barring K₁₂₀ Mg₄₀ S₄₀ combination.

□.....
Experimental results

Table 4.19: Interaction effect of different levels of K, Mg and S fertilizers application on Mg accumulation (g plant⁻¹) of Bt. cotton at harvest

Potassium x magnesium x sulphur				
	Mg₀		Mg₄₀	
	S₀	S₄₀	S₀	S₄₀
K₀	1.44	1.58	2.26	2.96
K₁₂₀	2.28	2.68	3.92	3.52
C.D. at 5% = 0.651				

4.5. EFFECT ON IMPORTANT PHYSICO-CHEMICAL PROPERTIES OF SOIL

Data presented in Table 4.20 are on pH (1:2.5), electric conductivity (dSm⁻¹) and organic carbon (g kg⁻¹). The available phosphorus (P₂O₅) (kg ha⁻¹), available potassium (K₂O) (kg ha⁻¹), exchangeable magnesium (me 100 g⁻¹ of soil) and available sulphur (mg kg⁻¹) status are given in Table 4.21. DTPA-Micronutrients content (mg kg⁻¹) at harvest of Bt. cotton are given in Table 4.22. The treatment effect was not significant on soil pH, EC, OC, available P₂O₅, available S and micronutrient content in soil at harvest of Bt. cotton. However the available K₂O and available Mg content exhibited significant variations due to different levels of K and Mg, wherein K @ 120 kg ha⁻¹ and Mg @ 40 kg ha⁻¹ registered significantly higher values of available potassium (229 kg ha⁻¹) and exchangeable magnesium (6.0 me 100 g⁻¹ of soil) than respective controls (K₀ and Mg₀) (Table 4.21).

□.....

.....Experimental results

Table 4.20: Effect of different levels of K, Mg and S fertilizers application on pH, EC and Organic Carbon content after harvest of Bt. cotton

Treatments	pH (1:2.5)	EC (dSm ⁻¹)	OC (g kg ⁻¹)
K₀	7.5	0.19	5.6
K₁₂₀	7.4	0.19	5.6
S. Em.±	0.05	0.003	0.08
C.D. at 5%	NS	NS	NS
Mg₀	7.4	0.19	5.4
Mg₄₀	7.5	0.19	5.8
S. Em.±	0.05	0.003	0.08
C.D. at 5%	NS	NS	NS
S₀	7.5	0.20	5.5
S₄₀	7.5	0.19	5.7
S. Em.±	0.05	0.003	0.08
C.D. at 5%	NS	NS	NS
Interaction Effect			
K X M	NS	NS	NS
K X S	NS	NS	NS
M X S	NS	NS	NS
K X M X S	NS	NS	NS
C.V. %	2.5	6.4	5.9

4.5.1. Effect on nutrient content in soil of Bt. cotton at 30, 60 and 90 DAS

The data on available potassium (kg ha⁻¹), exchangeable magnesium (me 100 g⁻¹ of soil) and available sulphur (mg kg⁻¹) content in soil of Bt. cotton at 30, 60 and 90 DAS are given in Table 4.23.

The soil sample analysis indicated that the available potassium (K₂O) was medium in soil at 30, 60 and 90 DAS with an overall mean of 250, 248 and 221kg ha⁻¹, respectively.

□.....
.....*Experimental results*

Similarly the available magnesium was sufficient in soil at 30, 60 and 90 DAS with an overall mean of 5.0, 4.9 and 5.1 me 100 g⁻¹ soil, respectively.

The data collected on available sulphur status of soil at 30, 60 and 90 DAS indicated that it was deficient during growth period of crop, the corresponding overall mean values were 6.4, 5.7 and 5.2 kg ha⁻¹ (Table 4.21).

Table 4.21: Effect of different levels of K, Mg and S fertilizers application on soil available P₂O₅, available K₂O, exchangeable Mg and available S after harvest of Bt. cotton

□.....

.....*Experimental results*

Treatments	Available P₂O₅ (kg ha⁻¹)	Availabl e K₂O (kg ha⁻¹)	Exchangeable Mg (me 100 g⁻¹ of soil)	Available S (mg kg⁻¹)
K₀	77.2	157	5.1	5.5
K₁₂₀	79.4	229	5.5	5.0
S. Em.±	1.4	4	0.2	0.2
C.D. at 5%	NS	13	NS	NS
M₀	77.8	191	4.7	5.2
Mg₄₀	78.8	194	6.0	5.3
S. Em.±	1.4	4	0.2	0.2
C.D. at 5%	NS	NS	0.6	NS
S₀	77.0	192	5.4	5.4
S₄₀	79.6	194	5.3	5.6
S. Em.±	1.4	4.0	0.2	0.2
C.D. at 5%	NS	NS	NS	NS
Interaction Effect				
K X M	NS	NS	NS	NS
K X S	NS	NS	NS	NS
M X S	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS
C.V. %	7.3	9.1	15.5	19.0

□.....

.....Experimental results

Table 4.22: Effect of different levels of K, Mg and S fertilizers application on soil DTPA-Micronutrients content after harvest of Bt. cotton

Treatments	DTPA-Micronutrients content (mg kg ⁻¹)			
	Fe	Mn	Zn	Cu
K₀	4.9	6.0	0.6	1.1
K₁₂₀	5.3	6.1	0.7	1.1
S. Em.±	0.3	0.3	0.03	0.05
C.D. at 5%	NS	NS	NS	NS
M₀	5.0	6.2	0.7	1.0
M₄₀	5.1	5.8	0.7	1.1
S. Em.±	0.3	0.3	0.03	0.05
C.D. at 5%	NS	NS	NS	NS
S₀	5.1	5.8	0.7	1.1
S₄₀	5.0	6.3	0.7	1.1
S. Em.±	0.3	0.3	0.03	0.05
C.D. at 5%	NS	NS	NS	NS
Interaction Effect				
K X M	NS	NS	NS	NS
K X S	NS	NS	NS	NS
M X S	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS
C.V. %	21.4	17.2	19.0	19.2

Table 4.23: Effect of different levels of K, Mg and S fertilizers application on available K₂O, available Mg and available S content at 30, 60 and 90 DAS of Bt. cotton

Treatments	Available K ₂ O (kg ha ⁻¹)			Exchangeable Mg (me 100 g ⁻¹ soil)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90

.....
Experimental results

K₀Mg₀S₀	237	232	205	5.1	4.9	4
K₀Mg₀S₄₀	247	216	203	5.5	5.2	5
K₀Mg₄₀S₀	227	249	204	4.5	4.9	4
K₀Mg₄₀S₄₀	251	257	219	4.9	5.1	5
K₁₂₀Mg₀S₀	256	267	226	4.8	4.2	4
K₁₂₀Mg₀S₄₀	257	248	231	5.1	4.9	5
K₁₂₀Mg₄₀S₀	268	252	233	5.4	4.8	6
K₁₂₀Mg₄₀S₄₀	256	264	245	4.7	5.2	5
Minimum	227	216	203	4.5	4.2	4
Maximum	268	267	245	5.5	5.2	6
Mean	250	248	221	5.0	4.9	5

V. DICSUSSION

The effects of K, Mg and S are reported while presenting the results of the experiment in previous chapter. In this chapter, it is contemplated to discuss the variations observed in growth, yield attributes, yield and nutrient content of the plant and soil status under influence of different treatments in details with an attempt to establish the “cause and effect” relationship in light of available evidences and relevant literature. The detailed discussion of various results obtained in the present study is given under following sub-headings.

5.1. EFFECT OF WEATHER

5.2. EFFECT ON GROWTH

5.3. EFFECT ON YIELD

5.4. EFFECT ON NUTRIENTS CONTENT IN PLANT

5.5. NUTRIENT ACCUMULATION BY PLANT

5.6. EFFECT ON IMPORTANT PHYSICO-CHEMICAL PROPERTIES OF SOIL

5.1 EFFECT OF WEATHER

Among the various factors responsible for affecting the yield and performance of crop, the weather conditions play a key role. The various weather parameters pertaining to 2012 *kharif* season are

presented in Table 3.1. It is evident from the data that all the meteorological parameters were congenial for normal growth and development of crop. The minimum and maximum temperatures (12.6°C to 27.8°C and 29.2°C to 38.1°C) were also normal and the average relative humidity was optimum during the crop period.

5.2. EFFECT ON GROWTH

5.2.1. Plant stand at harvest

The data presented in Table 4.1 represent the No. of plants per 30.24 m² at harvest of Bt. cotton as affected due to application of potassium, magnesium and sulphur fertilizers. The plant stand was significantly more under K₁₂₀, Mg₄₀ and S₄₀ than control. The uniform plant stand was maintained at the beginning by gap filling of plant raised in polythene bags. The reddening and drying of leaves besides wilt/parawilt problem in Bt. cotton is wide spread in country irrespective of crop variety or soil type which is likely to affect the plant stand at the final stage of the crop. The role of S in oilseed crops as well as effect of K on growth and quality of crops is reported by various scientists. There was significant beneficial effect of K and S application to maintain good growth of plant at harvest, while Mg application was not seen on plant stand (Fig.1 and 2.).

The data on plant stand revealed that plant at harvest was significantly improved due to K and S application probably due to alleviation of drying of plant due to their deficiency or reduced reddening. Both these nutrients have responded positively on account of medium availability of K and deficiency of S in the experimental soil (Table 3.3).

5.1.2. Plant height

The results of the investigation in Table 4.2 revealed that potassium, magnesium and sulphur fertilizer levels had no significant effect on plant height. However their combinations had difference on plant height at 30, 60, 90 DAS and at harvest stages of Bt. cotton. Contrary to the present finding Prasad (2000) reported significant improvement in plant height due to S @ 25 kg ha⁻¹ in cotton-Gobhi serson rotation at New Delhi. Sharma *et al.* (2000) from a study conducted at Hisar also reported similar findings.

The data on interaction effect showed that combined application of K X Mg was found significant to alter plant height (Table 4.3). The data on K X Mg interaction indicated that K₀Mg₀ combination was found significantly superior to all other combinations, which could be due to dominant effect of nitrogen as

recommended dose of fertilizer for cotton in Gujarat is only N. The N is known to influence cell elongation. Significantly lower height in other treatment combination could be due to profuse branches and more number of reproductive organs as soil was medium in available K status and deficient in available S (Table 3.3).

5.3. EFFECT ON YIELD

The results presented in Table 4.4 clearly indicate that application of potassium significantly increased seed cotton and stalk yield. Mg application increased only stalk yield and S application increased seed cotton and stalk yield as well as oil content of seed. (Table 4.4 and Fig.3).

5.3.1. Stalk yield

The increase in stalk yield due to K, Mg and S was to the tune of 48.6, 18.9 and 19.3 per cent over respective control. In case of stalk yield, the application of either K, Mg or S was noticed significant over respective control (Table 4.4 and also depicted in Fig.2). The highest stalk yield was found (1400 kg ha^{-1}) due to application of potassium @ 120 kg ha^{-1} . The improvement in stalk yield may be due to good growth in presence of K application (Plate.1). The similar results were reported by the Marschner (1986), Sangakkara *et al.* (2000), Cakmak *et al.* (1994) and Dhindsa *et al.* (1975). The

experimental soil had medium status of available potassium (Table 3.3), which is likely to give response to applied nutrient.

It has been established that potassium plays major role in CO₂ fixation and overall photosynthesis of plant and also synthesis of fiber and its quality.

Application of magnesium @ 40 kg ha⁻¹ significantly influenced stalk yield of Bt. cotton (1210 kg ha⁻¹) over control (971 kg ha⁻¹). The similar results were also reported by Ramesh *et al.* (1999). The reddening occurs due to reduced photosynthetic activity in the plant, which may be due to immobilization of Mg in cotton resulting into less crop canopy development.

Sulphur application @ 40 kg ha⁻¹ (1212 kg ha⁻¹) gave significantly higher seed cotton and stalk yield as well as seed oil content than control. The higher yield could be due to good vegetative growth of Bt. cotton. The good growth of Bt. cotton in presence of S shown in Plate.1 & 2. These results are in agreement with the findings of Prasad *et al.* (1994) at New Delhi and work carried out at AICRP on micronutrient Research project at Anand (Anon., 2012). The deficiency of sulphur reduces the concentration of chlorophyll, sugars, starch and protein in cotton leaves. The activity of ribonuclease decreases and that of catalase, peroxidase, acid phosphate and starch

also reduces by low status of available sulphur in soil. The experiment soil was deficient in available S (Table 3.3).

5.3.2. Seed cotton yield

Seed cotton yield improvement due to K and S was to the tune of 12.6 and 24.6 per cent over their respective control. The data are presented in Table 4.4 and also depicted graphically in Fig. 1. Combined application of potassium and sulphur (K X S) interaction indicated that the significantly the highest seed cotton yield (1557 kg ha⁻¹) was reported under K₁₂₀S₄₀ combination (Table 4.5). This might be due to increase in yield attributing characters, which has resulted in increase seed cotton yield. Similar results were reported by Pettigrew and Meredith (1997) who reported that K fertilization improved stem weight (21 %), seed (19 %) and lint (20 %) over control. Application of 100 Kg K₂O at Anand also improved seed cotton yield by 7.2 per cent over control (Anon., 2011-12).

The positive response of sulphur application on seed cotton yield was also reported by several workers viz., Prasad and Prasad (1994)., Sharma and Dungarval (1997)., Singh (1997)., Prasad (1998)., Sharma *et al.* (2000)., Dubey *et al.* (2001)., Muhammand *et al.* (2001)., Makhdum *et al.* (2001)., Singh and Kairon (2001)., Sharma and Kumawat (2005)., Dunn *et al.* (2008).

Although several workers have reported positive response on cotton yield due to Mg addition either through soil or foliar feeding, in the present experiment Mg did not give significant improvement in seed cotton yield due to its adequacy in soil as well as irrigation water. The experiment conducted by almost all the scientist have not tried graded levels of Mg, hence whatever yield improvement was seen is due to additive effect of N, P, K, Mg, S and other micronutrients.

5.3.3. Oil content (%)

An examination of results presented in Table 4.4 and also depicted in Fig. 3 showed significant increase in oil content (19.8 %) due to S application @ 40 kg ha⁻¹ over S₀. The improvement in oil content was to the tune of 15.8 per cent over control. As a result of sulphur deficiency the quality of cotton seeds deteriorated which was reflected in low content of oil under S₀ treatment. The similar results were found by Swan *et al.* (2006) due to S addition, who reported that application of potassium in form of potassium sulphate improved oil content of cotton seed of Egyptian cotton over control probably due to supply of sulphur inadvertently. Similarly Chatterjee *et al.* (2001) also noted that oil content of cotton seed is reduced due to deficiency of sulphur in soil.

5.4. EFFECT ON NUTRIENT CONTENT IN PLANT

5.4.1 Effect on nutrient content in leaf of Bt. cotton at 30, 60 and 90 DAS

5.4.1.1. Total K (%)

The cotton leaf concentration of K was determined at 30, 60 and 90 DAS (Table 4.6 and Fig. 4 & 5)

The overall mean concentration of K in lower leaves varied from 0.33 to 0.38 per cent at 90 and 30 DAS, respectively. There was maximum content of K (0.42 %) due to combined application of K, Mg and S ($K_{120}Mg_{40}S_{40}$) at 30 DAS.

In case of upper leaves, K concentration was maximum (0.89 %) due to K and Mg ($K_{120}Mg_{40}S_0$) application at 30 DAS. It ranged between 0.67 to 0.82 % during 90 and 30 DAS, respectively. The similar results were obtained in a study conducted under AICRP on micronutrient at Anand (Anon., 2012-13), wherein K content of leaf (0.84 %) was significantly increased over control (0.69 %) due to application of K @ 100 kg ha⁻¹.

5.4.1.2. Total Mg (%)

.....
.....*Discussion*

The cotton leaf concentration of Mg was determined at 30, 60 and 90 DAS and data are presented in Table 4.7 and also depicted in Fig. 6 & 7.

The overall Mg concentration in lower leaf of Bt. cotton at 30, 60 and 90 DAS was 2.87, 3.02 and 2.48 per cent, respectively. The corresponding Mg content in upper leaves was 3.21, 3.11 and 2.55 per cent during 30, 60 and 90 DAS of Bt. cotton. In general, Mg content was higher in upper leaves as compared to lower leaves, which could be due to its mobile nature in plant.

At 60 DAS, the Mg content was higher in both upper and lower leaf (3.38 and 3.28 %) due to combined application of K, Mg and S ($K_{120}Mg_{40}S_{40}$). Similar results were obtained in an experiment conducted at Anand (Anon., 2012-13).

5.3.1.3. Total S (%)

The concentration of S in cotton leaf was determined at 30, 60 and 90 DAS and data are presented in Table 4.8 and also depicted in Fig. 8 & 9.

The S content in lower leaves was 0.88, 0.88 and 0.79 per cent during 30, 60 and 90 DAS, respectively, while, it was 0.40, 0.40 and 0.32 % in case of upper leaves indicating immobile nature of S in plant. Similarly with the application of S @ 30 kg ha⁻¹ increase in S content in cotton leaf was recorded at Anand (Anon., 2012-13)

5.3.1.4 Effect on nutrient content in plant at harvest

The results presented in the previous chapter in Table 4.9 to 4.14 revealed that phosphorus, potassium, magnesium, sulphur and micronutrients contents (%) in stalk, leaf, lint and seed were not affected significantly due to application of potassium, magnesium and sulphur fertilizer levels at harvest of Bt. Cotton, except K content of leaf due to K application, S content of stalk, leaf and seed due to S application and Mg content of stalk as well as leaf due to Mg application. And also Cu content of leaf due to sulphur addition @ 40 kg ha⁻¹. None of the interaction effect of K, Mg and S was found to be significant with respect to nutrient content of different components of Bt. cotton crop.

The leaf content of K (0.73 %) and Mg (3.0 %) was increased significantly due to application of 120 kg K ha⁻¹ and application of 40 kg Mg ha⁻¹, respectively over their respective control. With the application of 40 kg S ha⁻¹, S (0.30 %) and Cu (5.0 ppm) contents were increased in leaf over its control (S₀) at harvest. The experiment conducted on Bt. cotton at Anand to study the response S application also gave similar results (Anon., 2012-13).

5.5 NUTRIENT ACCUMULATION BY PLANT

.....
.....*Discussion*.....

The data furnished in Table 4.15 are on K, Mg and S nutrient accumulation (g plant^{-1}) at harvest by Bt. cotton plant.

The application of K, Mg and S significantly influenced the accumulation of K, Mg and S in plant except accumulation of Mg and S due to application of S and K, respectively.

The data presented in Table 4.16 and 4.17 are on interaction effect K and S on accumulation of K and S in plant. The significantly higher accumulation of K and S (0.536 and $0.080 \text{ g plant}^{-1}$) was recorded due to combined application of K and S. The significantly higher S accumulation ($0.086 \text{ g plant}^{-1}$) was noticed due to combined application of Mg and S, but the same was on par with its individual application i.e. at S_{40} and Mg_{40} (Table 4.18). The data revealed that significant improvement was noticed due to different combinations except $K_0Mg_0S_{40}$ over control. The highest Mg accumulation (3.2 g plant^{-1}) was noticed under $K_{120} \times Mg_{40} \times S_0$, which was on par with combination of $K_{120} Mg_{40} S_{40}$ (Table 4.19). Similar trend was also reported from experiment conducted at Anand with the application of K, Mg and S in loamy sand soil on Bt. cotton (Anon., 2012-13).

5.4.2. Potassium, magnesium and sulphur status of soil at 30, 60 and 90 DAS

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.....*Discussion*

The data on available potassium (kg ha^{-1}), exchangeable magnesium ($\text{me } 100 \text{ g}^{-1}$ of soil) and available sulphur (mg kg^{-1}) content in soil of Bt. cotton at 30, 60 and 90 DAS are given in Table 4.21 and also depicted in Fig. 10, 11 & 12.

The soil sample analysis indicated that the overall available potassium was higher at 30 DAS (250 kg ha^{-1}) as compared to 60 and 90 DAS. The similar results were reported by Essington *et al.* (2002). No change in exchangeable magnesium status was noticed over the time which may be due to sufficient content of exchangeable magnesium in soil (Table 3.3). Similarly available sulphur (6.4 mg kg^{-1}) was higher at 30 DAS as compared to 60 & 90 DAS. The decrease in K and S status in soil, with the time (i.e. at 60 and 90 DAS over 30 DAS) indicated more utilization of K and S for better growth of Bt. cotton. The similar results were reported by Xinhua Yin *et al.* (2011) In general, the K, Mg and S status was improved with their respective application. The experiment conducted under ageis of AICRP on Micro, Secondary and Pollutant element Project also revealed similar results (Anon., 2012-13).

5.6 EFFECT ON IMPORTANT PHYSICO-CHEMICAL PROPERTIES OF SOIL

.....
.....*Discussion*

Data are presented in Table 4.22 to 4.24 are on pH (1:2.5), on electric conductivity (dSm^{-1}), organic carbon (g kg^{-1}), available phosphorus (P_2O_5) (kg ha^{-1}), available potassium (K_2O) (kg ha^{-1}), exchangeable magnesium ($\text{me } 100 \text{ g}^{-1}$ of soil), available sulphur (mg kg^{-1}) and DTPA-Micronutrients (mg kg^{-1}) after harvest of Bt. cotton.

The treatment effects on pH, EC, OC, available P_2O_5 , available S and micronutrient content in soil at harvest of Bt. cotton was not significant. The available K_2O (229 kg ha^{-1}) and exchangeable Mg ($6.0 \text{ me } 100 \text{ g}^{-1}$ of soil) were significantly improved due to their addition over control. The similar results were noted by Essington *et al.* (2002). Similarly, the K and Mg content in soil were also increased with the application of 100 kg ha^{-1} each of K and Mg at Anand (Anon., 2012-13).

VI. SUMMARY AND CONCLUSIONS

A field experiment was conducted on loamy sand soil of College Agronomy Farm, B.A. College of Agriculture, Anand Agricultural University, Anand to study the “Effects of K, Mg and S fertilizers on growth and yield of Bt. cotton grown on loamy sand soil of middle Gujarat”. The experiment was laid out in a factorial randomized block design with four replications and three fertilizer levels. The salient findings of the experiment presented and discussed in preceding chapters are summarized and concluded here under.

Summary:

1. Beneficial effect of K (@ 120 kg ha⁻¹) and S (@ 40 kg ha⁻¹) was noticed to maintain plant stand up to harvest.
2. Plant height of Bt. cotton was not altered significantly due to individual application of either K, Mg and S, while significantly the highest plant height was noticed in absence of application of both potassium and magnesium.
3. Stalk yield of Bt. cotton was increased significantly due to individual application of K, Mg or S.
4. Seed cotton yield of Bt. cotton was increased significantly due to individual application of K (120 kg ha⁻¹) and S (40 kg ha⁻¹) as well as combined effect of both K (120 kg ha⁻¹) and S (40 kg ha⁻¹) to Bt.

.....
Summary and conclusions

cotton. But Mg application @ 40 kg ha⁻¹ failed to increase seed cotton yield significantly.

5. Oil content (%) was significantly improved due to S application @ 40 kg ha⁻¹ over control (S₀).
6. Leaf K, Mg and S contents at harvest were affected significantly due to their individual application to Bt. cotton over control.
7. Available K₂O and exchangeable Mg content in soil were increased significantly due to their individual soil application.

Conclusion:

Application of 120 kg K₂O ha⁻¹ and 40 kg S ha⁻¹ was beneficial to increase seed cotton yield as well as oil content of Bt. cotton under sandy loam soil of middle Gujarat having medium potassium and low available sulphur status.

Line of Future research:

- 1) Similar study should be conducted for other promising Bt. Cotton varieties in *kharif* season.
- 2) It is also suggested to study the response of fertilizers with different organic manures *viz.*, Vermicompost, FYM, Biofertilizers etc.
- 3) Such a study should be conducted under different agro-climatic conditions on different soil type.

Summary and conclusions

- 4) Similar study should be conducted as a long term experiment to find out residual effect of applied nutrients in soil.
- 5) Attention should be paid for increasing the efficiency of the applied nutrients by different approaches like split-application, slow release fertilizers, need based fertilizer application, etc.
- 6) Site specific nutrient management study in Bt. cotton should be planned to solve problem of reddening/parawilt in Bt. cotton
- 7) Multi- disciplinary approaches are necessary to reduce leaf reddening/parawilt problem in Bt. cotton.
- 8) To create awareness among the farmers for balanced fertilization in Bt. cotton as recommended dose for traditional hybrid varieties of cotton in Gujarat is only nitrogen.

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DECLARATION

This is to certify that whole of the research work reported in the thesis in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** by the undersigned is a result of investigation done by him under the direct guidance and supervision of **DR. V. P. RAMANI**, Associate Research Scientist, Micronutrient Project (ICAR), Anand Agricultural University, Anand and no part of the research work has been submitted for any other degree so far.

Place: Anand

(Solanki Sandip M.)

Date: /11/2013

Counter Signed by:

(V. P. RAMANI)

MAJOR GUIDE

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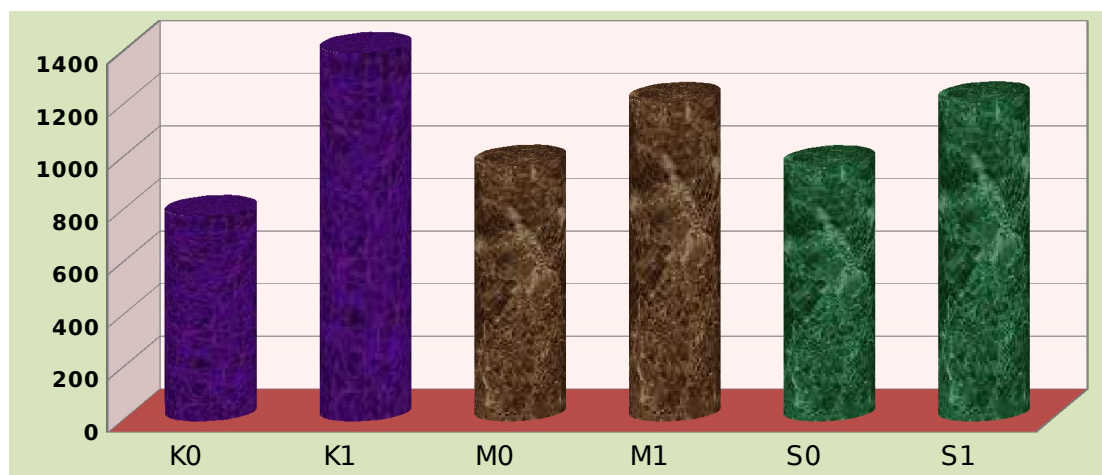


Fig 1: Seed cotton yield (kg ha⁻¹) of Bt. cotton as influenced by K, Mg and S fertilizer levels

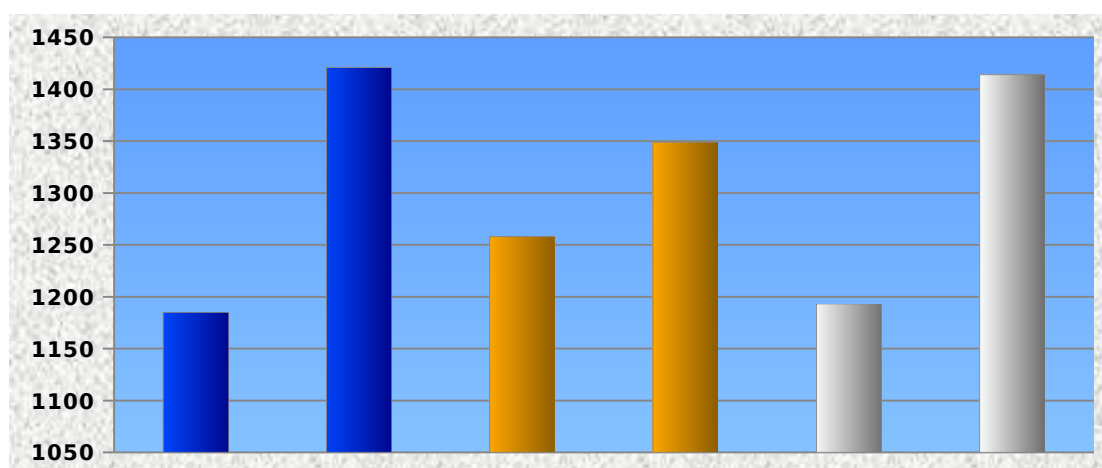


Fig 2: Stalk yield (kg ha^{-1}) of Bt. cotton as influenced by K, Mg and S fertilizer levels

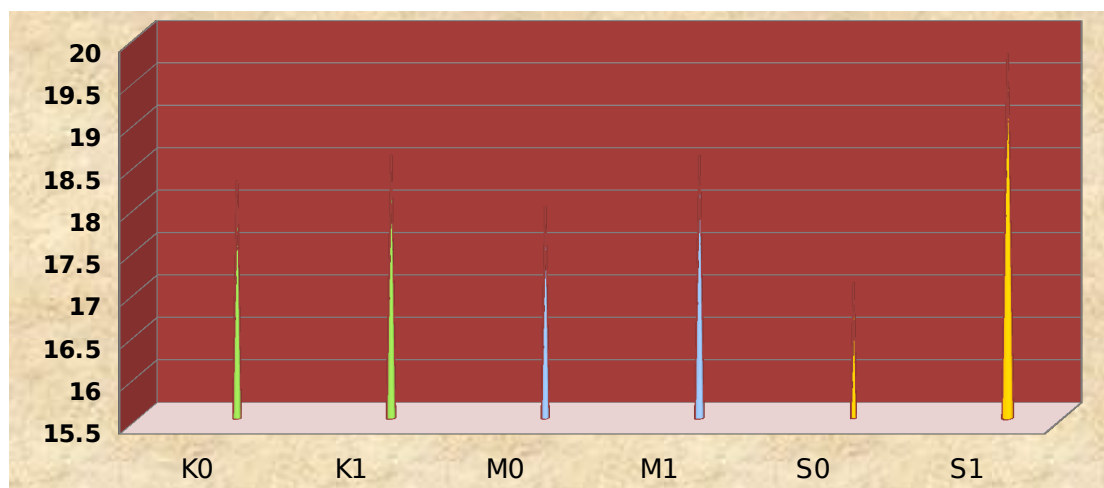


Fig 3: Oil content (%) of Bt. cotton as influenced by K, Mg and S Fertilizer levels

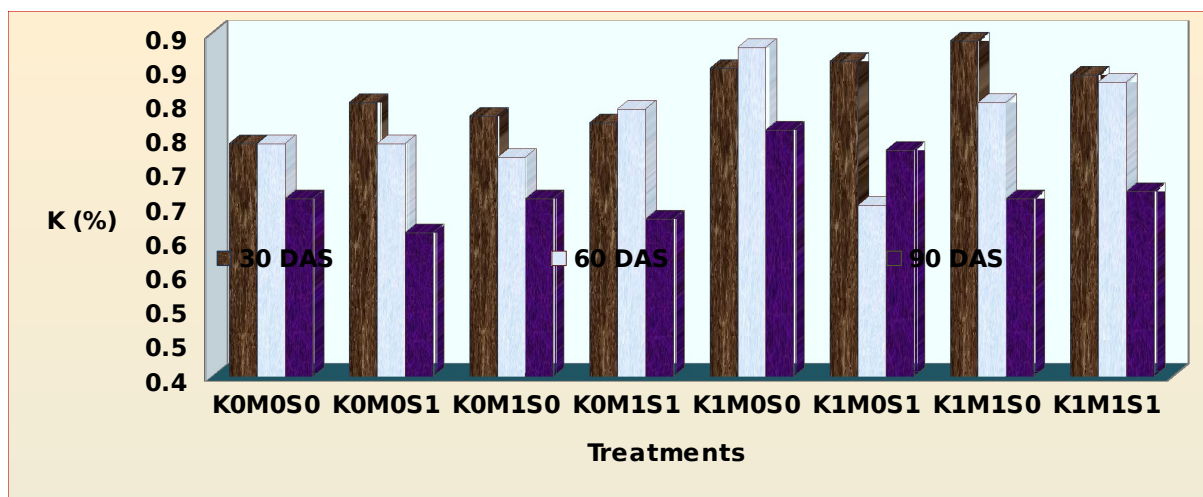


Fig 4: Influence of K, Mg and S fertilizer levels on K content (%) in upper leaf of Bt. cotton

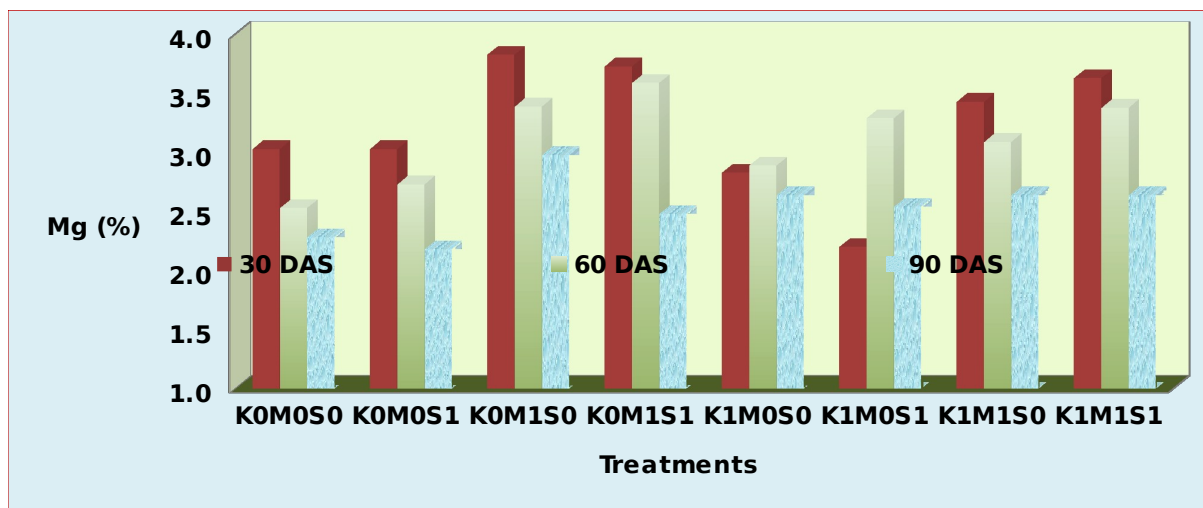


Fig 5: Influence of K, Mg and S fertilizer levels on Mg content (%) in upper leaf of Bt. cotton

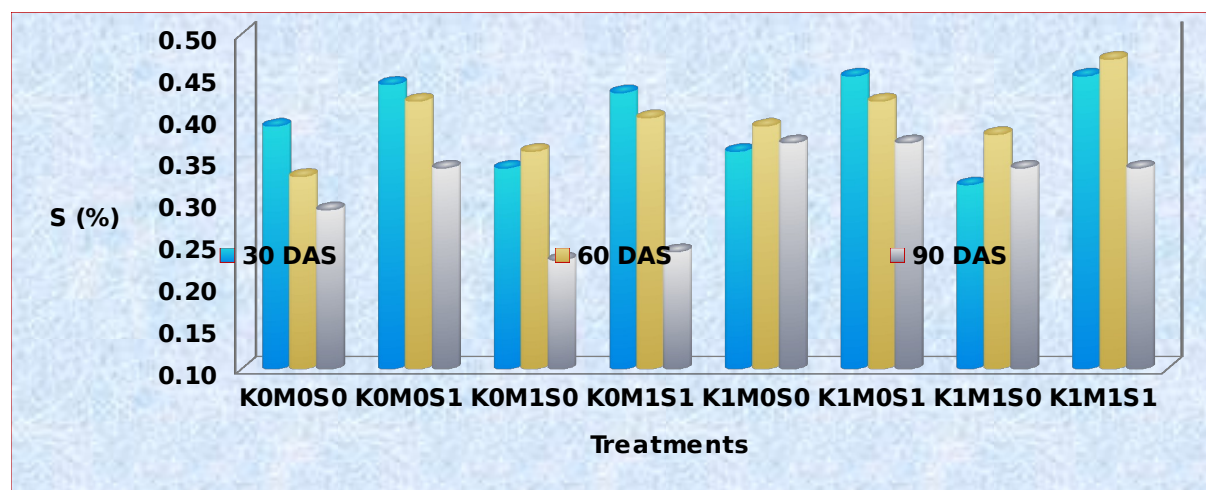


Fig 6: Influence of K, Mg and S fertilizer levels on S content (%) in upper leaf of Bt. cotton

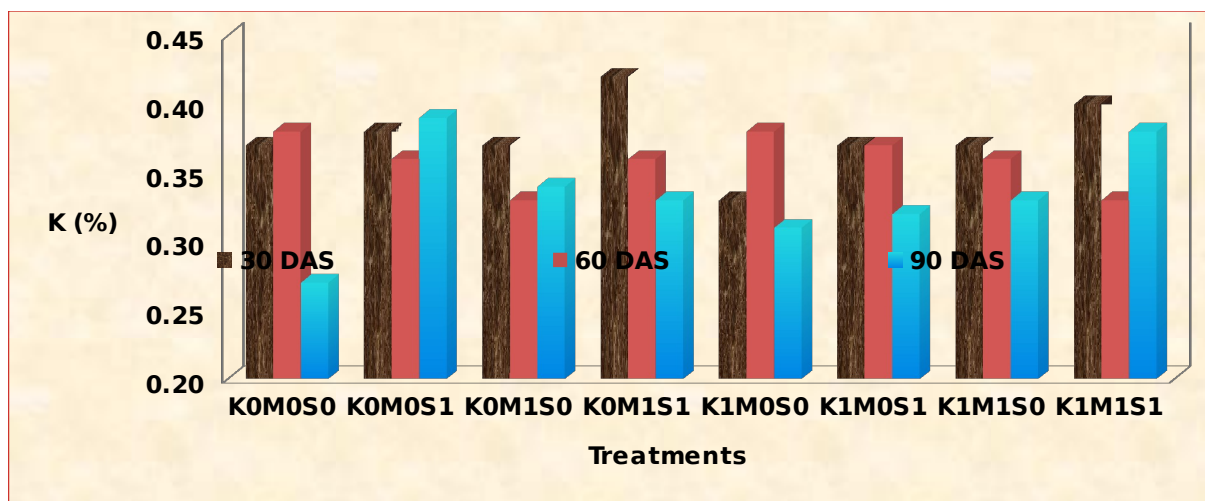


Fig 7: Influence of K, Mg and S fertilizer levels on K content (%) in lower leaf of Bt. Cotton

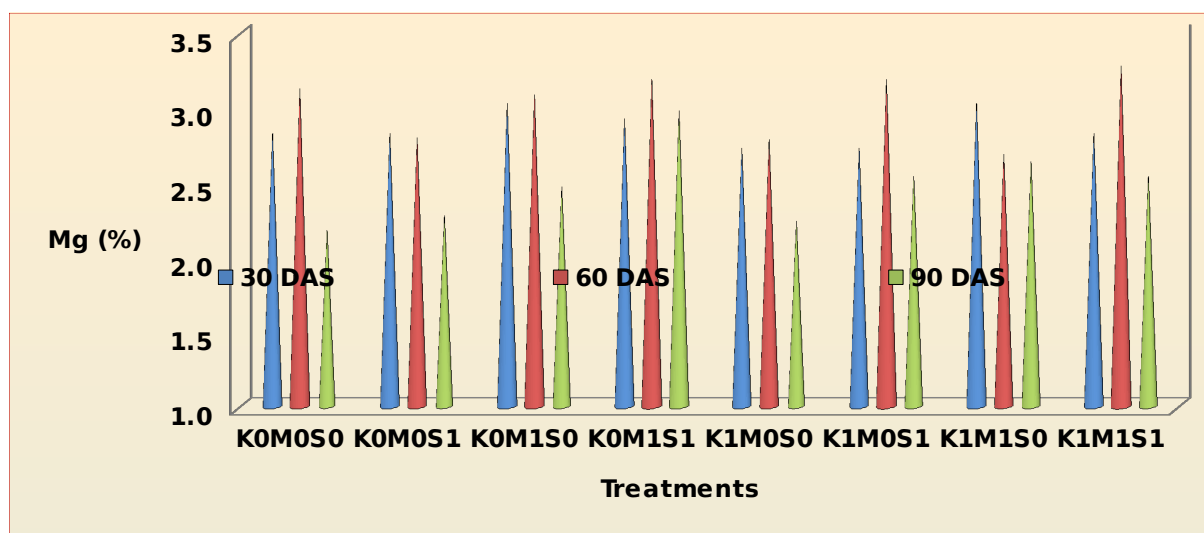


Fig 8: Influenced of K, Mg and S fertilizer levels on Mg content (%) in lower leaf of Bt. cotton

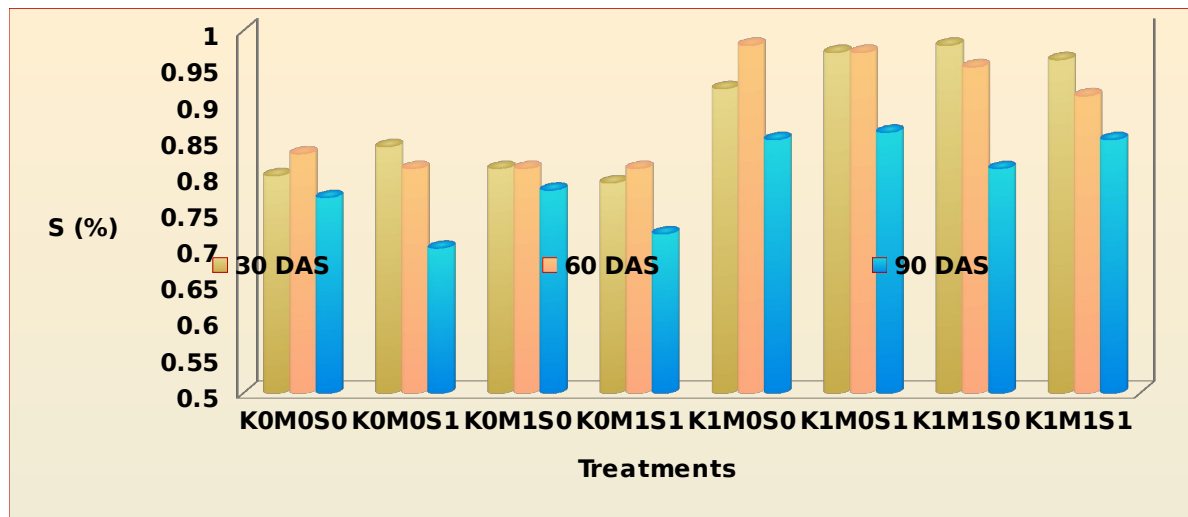


Fig 9: Influence of K, Mg and S fertilizer levels on S content (%) in lower leaf of Bt. cotton

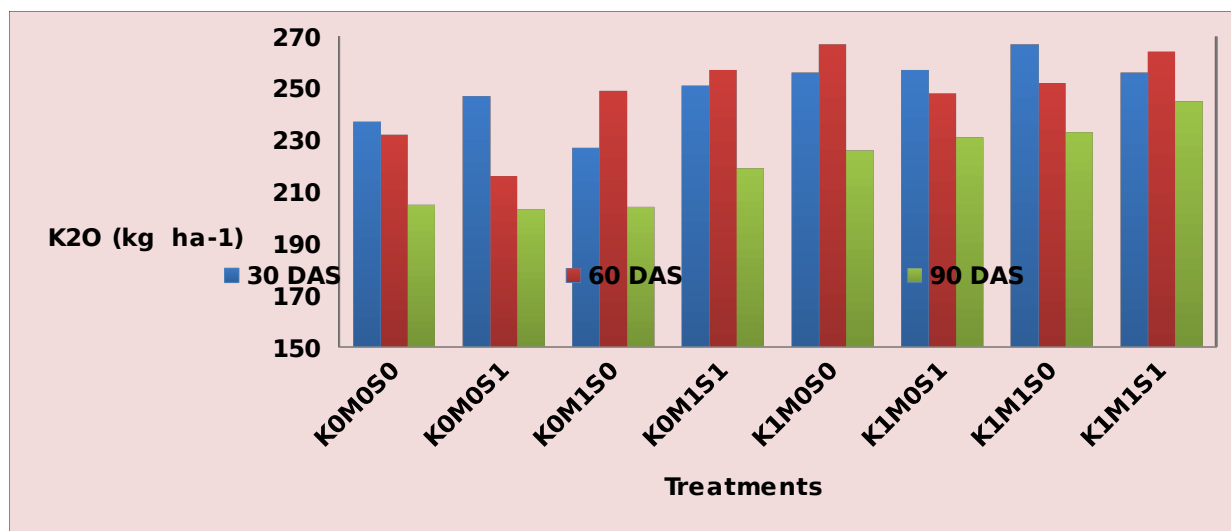


Fig 10: Available K_2O ($kg\ ha^{-1}$) as influenced by K, Mg and S fertilizer levels in Bt. cotton

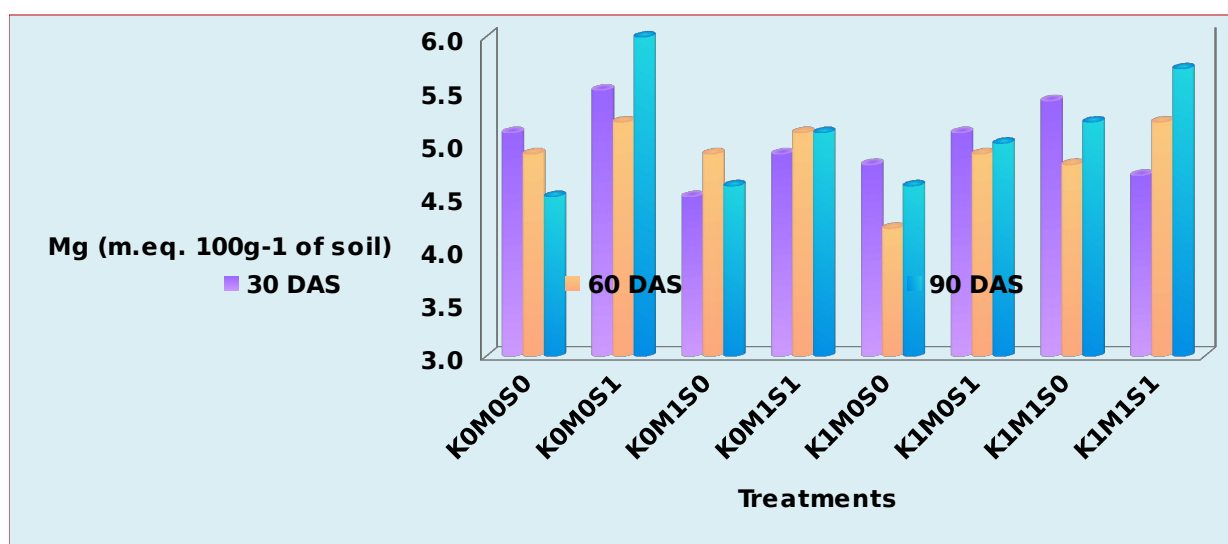


Fig 11: Exchangeable Mg (m.eq.100 g⁻¹ of soil) as influenced by K, Mg and S fertilizer levels in Bt. cotton

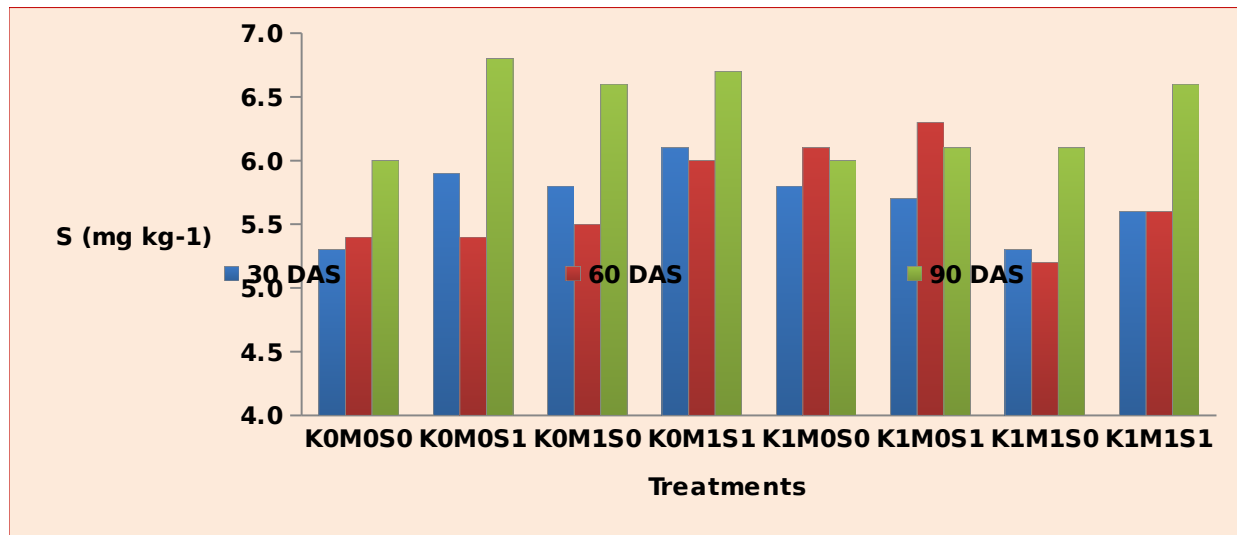


Fig 12: Available S (mg kg⁻¹) as influenced by K, Mg and S fertilizer levels in Bt. cotton

Layout of Experimental plot

0	6.3	7.3	13.6	14.6	20.9	21.9	28.2	29.2	35.5	42.8	43.8	50.1	51.1	57.4	N ↑	
4.8	K ₁₂₀ Mg ₀ S ₀	W A T E R C H A N N A L	K ₀ Mg ₄₀ S ₄₀	P A T H	K ₁₂₀ Mg ₄₀ S ₀	W A T E R C H A N N A L	K ₁₂₀ Mg ₀ S ₀	P A T H	K ₀ Mg ₄₀ S ₄₀	W A T E R C H A N N A L	K ₀ Mg ₄₀ S ₀	P A T H	K ₀ Mg ₄₀ S ₀	W A T E R C H A N N A L		K ₁₂₀ Mg ₄₀ S ₀
9.6	K ₁₂₀ Mg ₄₀ S ₀		K ₀ Mg ₄₀ S ₀		K ₁₂₀ Mg ₄₀ S ₄₀		K ₀ Mg ₀ S ₀		K ₁₂₀ Mg ₄₀ S ₄₀		K ₁₂₀ Mg ₄₀ S ₀		K ₀ Mg ₀ S ₀			K ₀ Mg ₄₀ S ₄₀
14.4	K ₁₂₀ Mg ₄₀ S ₄₀		K ₀ Mg ₀ S ₀		K ₀ Mg ₄₀ S ₀		K ₀ Mg ₄₀ S ₄₀		K ₀ Mg ₄₀ S ₀		K ₀ Mg ₀ S ₀		K ₁₂₀ Mg ₄₀ S ₄₀			K ₁₂₀ Mg ₀ S ₄₀
19.2	K ₁₂₀ Mg ₀ S ₄₀		K ₀ Mg ₄₀ S ₀		K ₀ Mg ₄₀ S ₀		K ₁₂₀ Mg ₀ S ₄₀		K ₁₂₀ Mg ₀ S ₀		K ₁₂₀ Mg ₀ S ₄₀		K ₀ Mg ₄₀ S ₀			K ₁₂₀ Mg ₀ S ₀
R-I			R-II			R-III			R-IV							

Table 4.13: Effect of K, Mg and S fertilizers application on Fe and Mn content in stalk, leaf, lint and

Treatments	Fe (ppm)				Mn (ppm)			
	Stalk	Leaf	Lint	Seed	Stalk	Leaf	Lint	Seed
K₀	10.4	151.1	109.58	5.2	26.6	63.6	4.6	8.2
K₁₂₀	11.9	146.0	116.68	8.4	27.5	64.2	4.4	6.6
S. Em.±	0.6	7.5	2.7	1.5	1.0	1.4	0.2	0.2
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Mg₀	11.0	142.9	108.98	6.8	26.2	64.1	4.4	7.1
Mg₄₀	11.2	154.2	117.28	6.7	27.5	63.6	4.6	7.7
S. Em.±	0.6	7.5	2.7	1.5	1.0	1.4	0.2	0.2
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
S₀	10.7	149.5	110.18	3.9	26.1	62.8	4.9	7.4
S₄₀	11.6	147.5	116.68	9.7	27.9	64.7	4.6	7.5
S. Em.±	0.6	7.5	2.7	1.5	1.0	1.4	0.2	0.2
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Interaction Effect								
K X M	NS	NS	NS	NS	NS	NS	NS	NS
K X S	NS	NS	NS	NS	NS	NS	NS	NS
M X S	NS	NS	NS	NS	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %	21.7	19.7	9.5	6.8	15.0	8.5	16.4	11.5

seed of Bt. cotton

Table 4.14: Effect of K, Mg and S fertilizers application on Zn and Cu content in stalk, leaf, lint and seed of Bt. cotton

Treatments	Zn (ppm)				Cu (ppm)			
	Stalk	Leaf	Lint	Seed	Stalk	Leaf	Lint	Seed
K₀	6.4	26.7	3.0	18.8	4.0	4.8	1.0	5.2
K₁₂₀	6.5	25.3	3.0	19.0	3.4	4.6	1.1	5.5
S. Em.±	0.2	1.1	0.2	0.6	0.1	0.2	0.1	0.1
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Mg₀	6.5	26.2	3.0	29.5	3.6	4.7	1.0	5.2
Mg₄₀	6.5	25.1	3.0	18.3	3.4	4.7	1.0	5.5
S. Em.±	0.2	1.1	0.2	0.6	0.1	0.2	0.1	0.1
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
S₀	6.5	26.2	2.9	18.3	3.4	4.4	1.1	5.4
S₄₀	6.5	26.1	3.1	19.5	3.5	5.0	1.0	5.3
S. Em.±	0.2	1.1	0.2	0.6	0.1	0.2	0.1	0.1
C.D. at 5%	NS	NS	NS	NS	NS	0.6	NS	NS
Interaction Effect								
K X M	NS	NS	NS	NS	NS	NS	NS	NS
K X S	NS	NS	NS	NS	NS	NS	NS	NS
M X S	NS	NS	NS	NS	NS	NS	NS	NS
K X M X S	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %	15.1	16.8	22.8	12.0	10.5	18.1	35.2	11.3

Table 4.17: Effect of different levels of K, Mg and S fertilizers application on available K₂O, available Mg and available S content at 30, 60 and 90 DAS of Bt. cotton

Available K ₂ O (kg ha ⁻¹)								
	K ₀ M ₀ S ₀	K ₀ M ₀ S ₄₀	K ₀ M ₄₀ S ₀	K ₀ M ₄₀ S ₄₀	K ₁₂₀ M ₀ S ₀	K ₁₂₀ M ₀ S ₄₀	K ₁₂₀ M ₄₀ S ₀	K ₁₂₀ M ₄₀ S ₄₀
30 DAS	237	247	227	251	256	257	267	256
60 DAS	232	216	249	257	267	248	252	264
90 DAS	205	203	204	219	226	231	233	245

Available Mg (me 100 g ⁻¹ of soil)								
	K ₀ M ₀ S ₀	K ₀ M ₀ S ₄₀	K ₀ M ₄₀ S ₀	K ₀ M ₄₀ S ₄₀	K ₁₂₀ M ₀ S ₀	K ₁₂₀ M ₀ S ₄₀	K ₁₂₀ M ₄₀ S ₀	K ₁₂₀ M ₄₀ S ₄₀
30 DAS	5.1	5.5	4.5	4.9	4.8	5.1	5.4	4.7
60 DAS	4.9	5.2	4.9	5.1	4.2	4.9	4.8	5.2

Available S (mg kg ⁻¹)								
	K ₀ M ₀ S ₀	K ₀ M ₀ S ₄₀	K ₀ M ₄₀ S ₀	K ₀ M ₄₀ S ₄₀	K ₁₂₀ M ₀ S ₀	K ₁₂₀ M ₀ S ₄₀	K ₁₂₀ M ₄₀ S ₀	K ₁₂₀ M ₄₀ S ₄₀
30 DAS	5.3	5.9	5.8	6.1	5.8	5.7	5.3	5.6
60 DAS	5.4	5.4	5.5	6.0	6.1	6.3	5.2	5.6
90 DAS	6.0	6.8	6.6	6.7	6.0	6.1	6.1	6.6

Table 4.18: Effect of different levels of K, Mg and S fertilizers application on K, Mg and S content in upper leaf at 30, 60 and 90 DAS of Bt. cotton

K (%)								
	$K_0M_0S_0$	$K_0M_0S_{40}$	$K_0M_{40}S_0$	$K_0M_{40}S_{40}$	$K_{120}M_0S_0$	$K_{120}M_0S_{40}$	$K_{120}M_{40}S_0$	$K_{120}M_{40}S_{40}$
30 DAS	0.37	0.38	0.37	0.42	0.33	0.37	0.37	0.40
60 DAS	0.38	0.36	0.33	0.36	0.38	0.37	0.36	0.33
90 DAS	0.27	0.39	0.34	0.33	0.31	0.32	0.33	0.38

Mg (%)								
	$K_0M_0S_0$	$K_0M_0S_{40}$	$K_0M_{40}S_0$	$K_0M_{40}S_{40}$	$K_{120}M_0S_0$	$K_{120}M_0S_{40}$	$K_{120}M_{40}S_0$	$K_{120}M_{40}S_{40}$
30 DAS	2.83	2.83	3.03	2.93	2.73	2.73	3.03	2.83
60 DAS	3.13	2.80	3.09	3.19	2.79	3.19	2.69	3.28
S (%)								
	$K_0M_0S_0$	$K_0M_0S_{40}$	$K_0M_{40}S_0$	$K_0M_{40}S_{40}$	$K_{120}M_0S_0$	$K_{120}M_0S_{40}$	$K_{120}M_{40}S_0$	$K_{120}M_{40}S_{40}$
30 DAS	0.80	0.84	0.81	0.79	0.92	0.97	0.98	0.96
60 DAS	0.83	0.81	0.81	0.81	0.98	0.97	0.95	0.91
90 DAS	0.77	0.70	0.78	0.72	0.85	0.86	0.81	0.85

Table 4.19: Effect of different levels of K, Mg and S fertilizers application on K, Mg and S content in

lower leaf at 30, 60 and 90 DAS of Bt. cotton

K (%)								
	$K_0M_0S_0$	$K_0M_0S_{40}$	$K_0M_{40}S_0$	$K_0M_{40}S_{40}$	$K_{120}M_0S_0$	$K_{120}M_0S_{40}$	$K_{120}M_{40}S_0$	$K_{120}M_{40}S_{40}$
30 DAS	0.74	0.8	0.78	0.77	0.85	0.86	0.89	0.84
60 DAS	0.74	0.74	0.72	0.79	0.88	0.65	0.8	0.83
90 DAS	0.66	0.61	0.66	0.63	0.76	0.73	0.66	0.67

Mg (%)								
	$K_0M_0S_0$	$K_0M_0S_{40}$	$K_0M_{40}S_0$	$K_0M_{40}S_{40}$	$K_{120}M_0S_0$	$K_{120}M_0S_{40}$	$K_{120}M_{40}S_0$	$K_{120}M_{40}S_{40}$
30 DAS	3.03	3.03	3.83	3.73	2.83	2.2	3.43	3.63
60 DAS	2.53	2.73	3.39	3.59	2.89	3.29	3.09	3.38
90 DAS	2.28	2.18	2.98	2.48	2.64	2.54	2.64	2.64

S (%)								
	K₀M₀S₀	K₀M₀S₄₀	K₀M₄₀S₀	K₀M₄₀S₄₀	K₁₂₀M₀S₀	K₁₂₀M₀S₄₀	K₁₂₀M₄₀S₀	K₁₂₀M₄₀S₄₀
30 DAS	0.39	0.44	0.34	0.43	0.36	0.45	0.32	0.45
60 DAS	0.33	0.42	0.36	0.4	0.39	0.42	0.38	0.47
90 DAS	0.29	0.34	0.23	0.24	0.37	0.37	0.34	0.34



Plate 1: Effect of sulphur on growth of Bt. cotton



Plate 2: Effect of potassium and sulphur on growth of Bt. cotton